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Appendix O – Natural Hazards Risk Assessment

Natural Hazards and Geotechnical Assessment

Wellington Sludge Minimisation Facility (SMF)

Prepared for Wellington City Council
Prepared by Beca Limited

7 July 2022

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Revision History

Revision Nº	Prepared By	Description	Date
1	Philip Robins	Draft for Review	28 April 2022
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Document Acceptance

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on behalf of	Beca Limited		

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Appendices

Executive Summary

The Wellington City Council is preparing a notice of requirement to alter the existing designation at Moa Point to provide for the construction, operation, and maintenance of a new Sludge Minimisation Facility to the west of the existing wastewater treatment plant off Stewart Duff Drive, Wellington.

This report considers the geotechnical aspects of the site and the natural hazards that should be considered as part of the proposed site development. This study has been made using geotechnical information from various studies undertaken at the site and adjacent properties. No additional site investigations and analysis have been undertaken as part of this assessment.

The Geotechnical Seismic Hazards and Geotechnical Climatic Hazards were considered separately. The geotechnical seismic hazards considered to potentially impact the site are fault rupture, site-specific seismic hazard assessment, and liquefaction and cyclic softening.

As no active faults are mapped through the site the risk of direct fault rupture is assessed to be low.

A site-specific seismic hazard study was conducted in accordance with the requirements specified in NZS1170.5:2004, and the Waka Kotahi/ NZ Transport Agency Bridge Manual (Rev 3). This study documented in “SMF Moa Point Project Site-specific Seismic Hazard Assessment”, was prepared for WCC and forms part of the consenting documentation.

The Greater Wellington Regional Council (GWRC) hazards data indicates that there is no risk of liquefaction at the site. This is consistent with the soil profile that indicates in-situ rock being near to the surface.

The geotechnical climatic hazards considered to potentially impact the site are flooding and slope stability. Localised flooding and adequate drainage provisions will be addressed through detailed design. The assessment shows that the rock cut slopes (slope stability) pose a moderate to high probability of affecting the proposed development. Previous instabilities and potential for future instabilities have been identified on existing slopes. The stabilisation of existing rock cut slopes near the proposed SMF development is required. Rock slope stabilisation using rock anchors and mesh will reduce the risk affecting the proposed development to low.

1 Introduction

1.1 Overview

The Wellington City Council (WCC) is preparing a notice of requirement (NOR) to alter existing designation 58 (Moa Point Drainage and Sewage Treatment) to provide for the construction, operation, and maintenance of a new Sludge Minimisation Facility (SMF) to the west of the existing Moa Point wastewater treatment plant (WWTP) off Stewart Duff Drive, Moa Point. The location of the proposed SMF is shown in Figure 1 below.

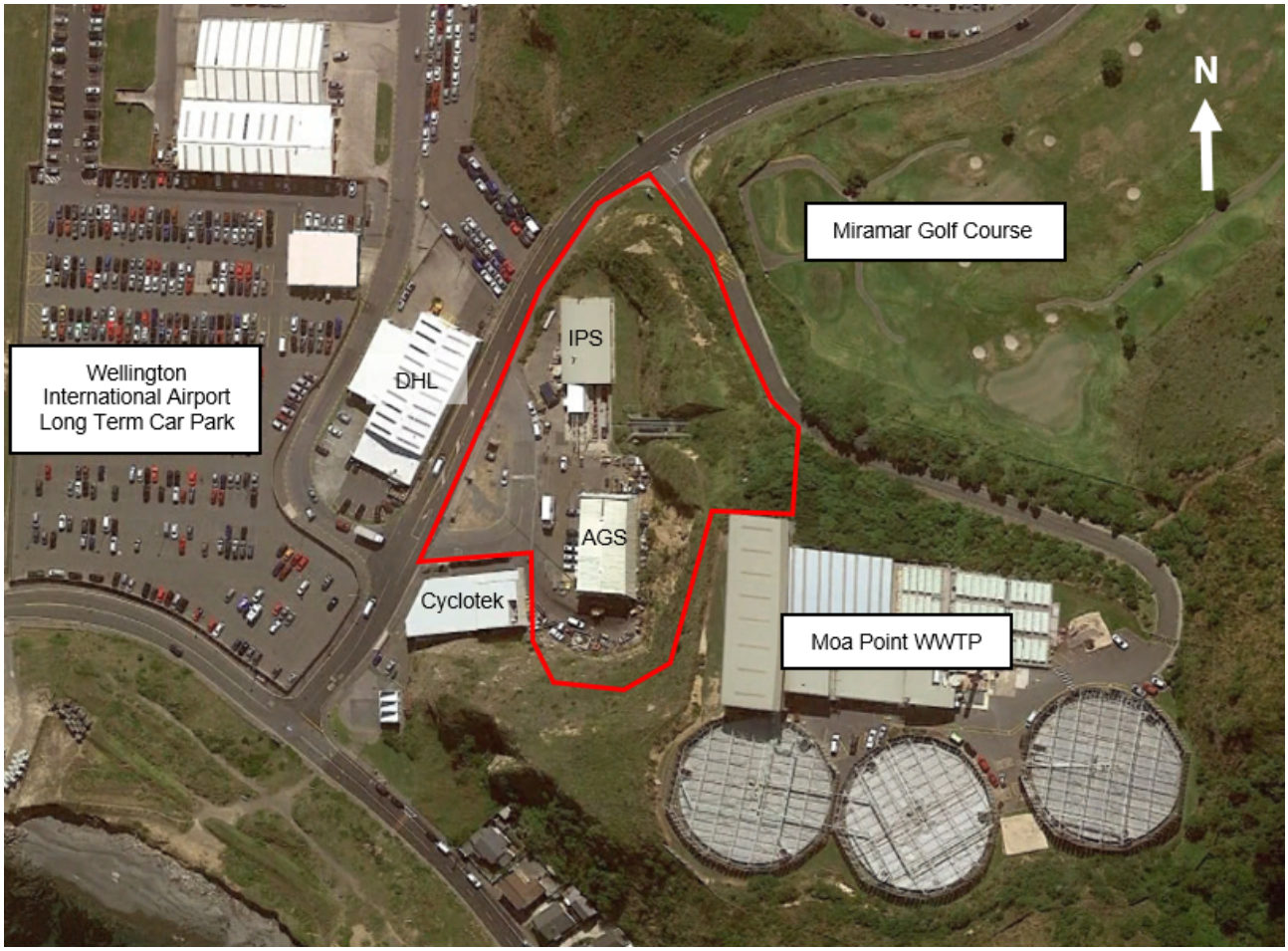


Figure 1: Location of the SMF site (shown in red)

1.2 Proposed Development

The proposed development is a new sludge minimisation facility (SMF) on land adjacent to the existing Moa Point wastewater treatment plant (WWTP). The SMF will comprise the following key buildings/structures:

- Two large cylindrical tanks (digesters),
- A three-storey Main Process Room building, and
- A three-storey Energy Centre building

The SMF is required to stabilise and reduce the volume of sewage sludge arising from Wellington City's existing wastewater treatment processes, which is currently discharged to landfill. The long-term intention is to make beneficial re-use of the resultant sludge product to avoid the need to discharge sludge to landfill.

1.3 Purpose and scope of this report

This report has been prepared in support of the Notice of Requirement (NOR) to alter designation 58 and associated resource consents which in turn would authorise, under the RMA, the construction, operation, and maintenance of the Project.

The altered designation and resource consents will provide for:

- a new Sludge Minimisation Facility
- necessary construction activities, including earthworks and slope stabilisations works
- formation of new vehicular access/egress
- associated connections to the existing Moa Point WWTP and local stormwater networks
- landscaping.

This report is focused on the geotechnical aspects of the site and the natural hazards that should be considered as part of the proposed site development.

This Natural Hazards and Geotechnical Assessment has been made using geotechnical information from various studies undertaken at the site and adjacent properties. No additional site investigations and analysis have been undertaken as part of this assessment.

2 Site Description

The SMF site has been highly modified and comprises an area of mostly flat land adjoining Stewart Duff Drive, Moa Point, to the southeast of the runway at Wellington International Airport enclosed by a former quarry headwall on the northern, eastern and southern boundaries. The flat area of land is largely previously developed, comprising an existing inlet pump station (IPS) and associated infrastructure, together with an Aviation Ground Services (AGS) building - formerly containing inlet screening facilities for the Moa Point WWTP) – now used for repair/maintenance of airport service vehicles. The wider flat area of land is predominantly surfaced in hard standing and provides for staff parking and machinery / equipment storage associated with the range of on-site uses. A small, grassed area is located behind the pump station and the embankments are partially vegetated.

Immediately adjoining the site to the south is a building housing a pharmaceuticals manufacturer and laboratory (trading as Cyclotek).

The northern boundary of the site abuts an access road to the Moa Point WWTP. The access road is sealed, with a narrow footway on the northern side. It is understood that the access road was carved into a former ridgeline and hence has rock underlain vegetated embankments on either side. Established tree planting is also present either side of the access road on the eastern stretch of the road.

To the west, the site is abutted by Stewart Duff Drive, a private road owned and controlled by WIAL. Stewart Duff Drive is accessible to public traffic and provides access to the airport (including long-stay parking), a DHL logistics facility, Miramar Golf Course and the aforementioned Cyclotek laboratory.

The majority of the site is paved with asphalt, and the AGS building is contained within a bund (which we understand is a feature of its former use as the Milliscreen Building). The eastern side of the AGS building is about 32m in length (N-S) running parallel to the former quarry slope. The slope is about 30m high with overall length about 120m; the AGS building is located along the southern half of the slope.

The northern half of the slope is about 45° and relatively stable, whereas the southern half has an irregular profile ranging from about 30° (debris fan) to 60°, and locally steepened to 80°. The slope is vegetated with low scrub/gorse (no large trees present), with bare rock and soil in areas of previous instability.

3 Published Geology

The site is to the east of Lyall Bay, at the south end of the Miramar Peninsula. The published geological maps (Begg and Mazengarb, 1996; Begg and Johnston, 2000) indicate the site is underlain by Rakaia Terrane (Torlesse Complex) greywacke rock of Late Triassic to early Jurassic age.

Wellington greywacke rock consists of fine-grained sandstone with variable amounts of interbedded mudstone (argillite), and is extensively faulted, tilted and folded, with very closely-spaced to closely-spaced joints (fractures). The geological map indicates a steep (about 70°) west to northwest dip on the rock bedding in this general area (consistent with what we observed on site).

4 Site History

The site is located on the floor of a former quarry, which historical aerial photographs suggest was operated from as early as 1938, and through to at least the early 1950s to win fill for the construction of the Wellington Airport reclamation. The historical aerial photographs (Figure 2) show the transformation of the coastline and the quarry for the period 1938 to present. It can be seen from these photographs that the natural west-facing slope at the headland was less steep in 1938, compared with the unstable former quarry slope seen today.

We understand the upper part of the quarried area (upslope of the present cut) was a landfill at various times, including during the construction of Wellington International Airport. The ground investigations for Moa Point WWTP confirmed the presence of refuse in the area, which was later removed prior to construction of the WWTP in 1996 (Beca Stevens, 1990).

The AGS building was built in 1988 - 1989 as the Milliscreen Building for sewage treatment, which was constructed to be a temporary structure. Earthworks involved widening of the building platform by excavation of the quarry slope toe, which steepened the lower 10m height of the slope to about 60°. We understand a landslip occurred not long after that excavation, as described in a report by Rankine and Hill in July of 1989, and summarised in the Beca Stevens (1990) report as follows:

A. The slip was mainly a block of rock failing on a semi-continuous outward dipping defect in the rock mass, which daylighted in the quarry face.

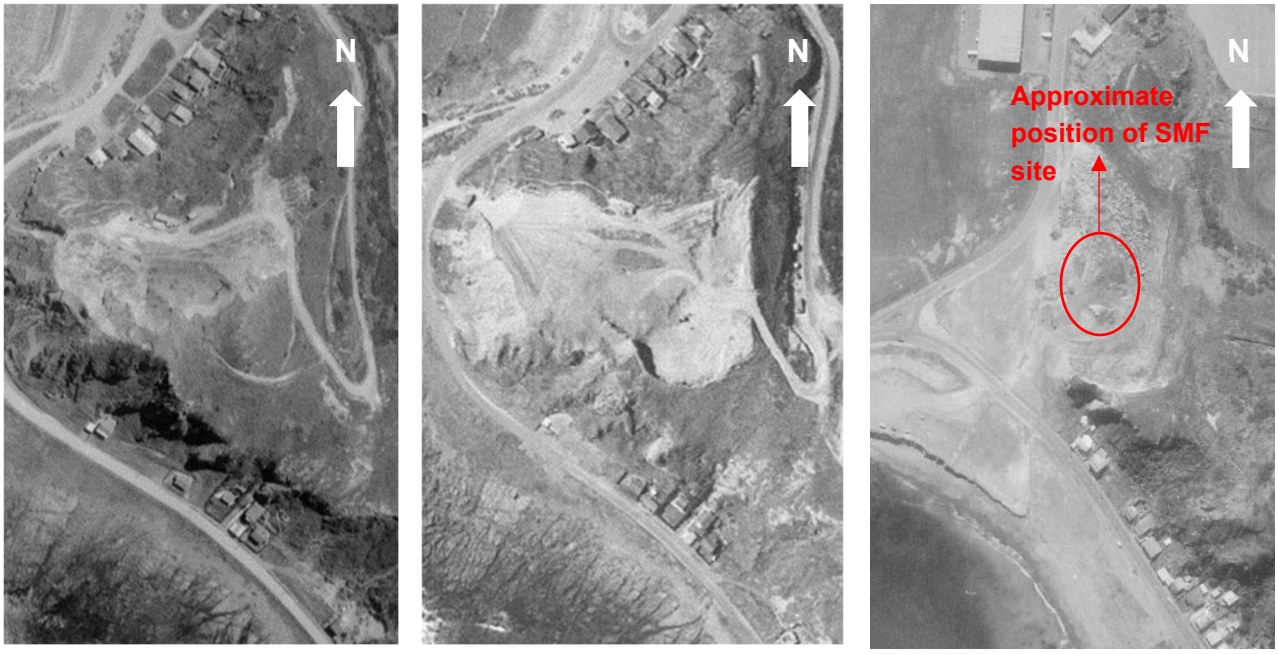
B. A secondary part of the failure was an about 8m wide zone to the south (*behind the AGS building*), possibly a reactivation of an older slope failure, adjacent to a more resistant zone of rock.

C. The central and southern parts of the quarry face and recent toe cut were relatively stable (*in about 1989*).

D. Ongoing periodic failure was expected toward the north end of the cut, and the report recommended stability of the slope be reassessed should the Milliscreen Plant be used for more than 10 years (*i.e. reassessment would have been required at about the year 2000*).

The Beca Stevens (1990) report also describes an old failure scarp offset 10m -15m horizontally from the upper quarry face and extending some 70m length. It is unclear exactly where this feature was located as it appears works to construct the WWTP access road and further instability in subsequent years have obscured it.

A topographic contour plan prepared in December 1989 (prior to the failure noted above) shows a triangular notch in the cut slope at the north end of the AGS building, with the easternmost part reaching an elevation of 28m. Current topographic contours (WCC Webmaps) show this feature is still present and has not regressed further upslope since 1989; the easternmost extent is still at about 28m elevation.



1938 **1941** **1980**

Figure 2: Historical aerial photographs.

5 Site Investigations

5.1 Previous Geotechnical Investigations

In 1989 Beca Steven (1990) undertook ground investigations for the (then proposed) WWTP at Moa Point, immediately upslope (east) of the AGS Building, at the Miramar Golf Course and in the area surrounding the current Moa Point WWTP. Those investigations included machine boreholes, test pits, laboratory analyses, as well as geophysical (seismic refraction) surveys to interpolate ground conditions between the bores and pits.

The boreholes identified a generalised profile of:

- Sand (both cover for landfill refuse, and natural aeolian deposits)
- Refuse (landfill)
- Soil and rock fill
- Colluvium (typically in gullies)
- *In-situ* completely to highly weathered greywacke rock, and
- *In-situ* moderately weathered greywacke rock.

The locations of the test pits and boreholes are shown on the site plan in Appendix A. The Beca Steven (1990) investigation data is appended in the Geotechnical Factual Report (Appendix A).

In 2019 Wellington International Airport Limited asked Beca for a rockfall assessment to be undertaken for the eastern slope behind the AGS Building. The rockfall assessment (using the 2007 AGS guidelines) indicated that without remediation further rockfalls at the site are “likely” to “almost certain”, putting the building at “moderate” to “high” risk (Beca, 2019).

5.2 Current Geotechnical Investigations

Geotechnical investigations were undertaken by Beca as part of the current project, and included:

- 6 machine boreholes up to 15.5m depth
- Downhole shear wave velocity testing
- Laboratory testing comprising: (a) 6 UCS tests, and (b) 2 wash gradings.

Factual data from the geotechnical investigations is presented in the Geotechnical Factual Report (Beca, 2021) and should be read in conjunction with this report. The locations of investigations are shown on Figure 3 below.

Figure 3: Recent Geotechnical Investigations

6 Soil Profile and Groundwater

The machine boreholes typically encountered fill overlying moderately to slight weathered greywacke. Table 1 below summarises the typical ground profile encountered during the investigations.

Table 1: Typical Ground Profile

Layer	Description	Approximate depth to top of unit (m bgl)	Unit thickness (m)
1	Fill	0	1.1 to 2.1
2	Completely Weathered (CW) Greywacke	0	0 to 0.8
3	Moderately (MW) to slightly Weathered (SW) Greywacke	0.8 to 2.1	>15

One standpipe piezometer was installed in BH01 screened over a depth range from 0.5m to 3.5m below ground level (bgl). A Solinst Level Logger was installed into BH01 on 22 October 2021 which records groundwater levels every half hour. Groundwater data from the loggers will be retrieved at a later date. Based on our groundwater measurements during drilling the groundwater level is about 5m bgl.

7 Geotechnical Seismic Hazards

7.1 Fault Rupture

The nearest fault is the Evans Bay Fault, which runs N-S through Evans Bay, about 1km west of the site. This fault is considered 'active'; there is understood to be indirect evidence (displacement of sediments) suggesting there has been late Quaternary (last 500 thousand years to 1 million years) displacement along it (Begg and Mazengarb, 1996). Recent studies by Barnes et al (2018) estimate the fault has had one sea-floor rupturing earthquake in the past 10,000 years and is capable of generating earthquakes of magnitude (Mw) greater than 7. However, there are no published rupture characteristics for this fault.

As no active faults are mapped through the site the risk of direct fault rupture is assessed to be low.

7.2 Site-Specific Seismic Hazard Assessment

A site-specific seismic hazard study was conducted in accordance with the requirements specified in NZS1170.5:2004, and the Waka Kotahi/ NZ Transport Agency Bridge Manual (Rev 3). This study documented in "SMF Moa Point Project Site-specific Seismic Hazard Assessment", was prepared for WCC and forms part of the consenting documentation. The study included:

- Probabilistic Seismic Hazard Analysis and development of site-specific hazard curves and acceleration values for return periods of 25, 100, 250, 500, 1000, and 2500 years.
- Development of site-specific Uniform Hazard Response Spectra for return periods of 25, 100, 250, 500, 1000 and 2500 years. Results are provided in graphical and tabulated form.
- Provision of Elastic Design Response Spectra for use in Engineering Design in accordance with principles adopted in NZS1170.5:2004.
- Disaggregation of the seismic hazard, at PGA, Sa (0.5s) and Sa (3s) for the SLS, SLS2 and ULS return periods (i.e.: 25-year, 500-year, and 2500-year return periods). The Mean, and Mode earthquake magnitudes will be determined to inform geotechnical engineering design.
- Deterministic Seismic Hazard Analysis (DSHA) based on selected event rupture scenarios to identify Maximum Considered Earthquake candidates and their characteristics, to inform the Ultimate Limit State where applicable.
- Provision of recommendations for vertical response spectrum for engineering design.

7.3 Liquefaction and Cyclic Softening

Loose saturated sandy soils can be subject to significant strength loss under strong seismic shaking due to a phenomenon known as liquefaction. Liquefaction can have a number of significant effects where it occurs, including large lateral displacements affecting coastal or riverbank slopes (termed lateral spreading), post liquefaction settlements (due to the densification of the affected sandy layers and loss of material to the surface) and potentially large and uneven settlement of shallow founded structures underlain by liquefiable soils.

Soft clayey soils can also lose strength due to a similar phenomenon known as cyclic softening. Cyclic softening is a liquefaction related phenomenon that occurs where cohesive soils are sheared during strong earthquake shaking. Cyclic softening can cause a significant strength loss in sensitive soils and may result in a number of liquefaction-like consequences including slope instability, building settlement, or tilting.

The Greater Wellington Regional Council (GWRC) hazards data (available through their online GIS maps) indicates that there is no risk of liquefaction at the site. This is consistent with the soil profile that indicates *in-situ* rock being near to the surface.

8 Geotechnical Climatic Hazards

8.1 Flooding

The GWRC flood hazard map indicates the site is not prone to flooding. However, the WCC flood zones map shows potential for localised flooding in a 1 in 100-year storm event (1 in 100-year annual return interval plus 20% climate change intensity) and assign a flood hazard Level 1 which corresponds to a low risk. Note the effects on flooding due to sea level rise have not been considered. The effects of sea level rise have been considered in the Coastal Erosion Hazard Assessment Reporting.

The above considers the current climatic and shoreline conditions (i.e.: present day risk), projected changes in shoreline and the effects of sea level rise which are expected to increase the risk of flooding.

8.2 Slope Stability

The GWRC GIS emergency management map gives slope failure risk ratings ranging from 1 - low, to 5 – high (largely based on average slope angles). The slopes to the east/south of the site (east of the AGS building) are mapped as having a slope stability risk rating of 5 (high).

The Beca (2019) report for the AGS building noted the *in-situ* greywacke rock of this former quarry slope to have closely to very closely (20mm to 200mm) spaced and often persistent defects several metres in length. A dominant planar joint set near-parallel to the slope face (60°- 70°) daylights in the west-facing slope. Rock slabs undergo planar/translation sliding along these defects, breaking up into cobbles and boulders up to 0.5m downslope, forming a debris fan. Some other joints intersect the main slope-parallel set, forming wedge failures. Most of the instability is in the centre of the cut area, the slopes to the north and south ends of the cut appear relatively stable.

This rock cut slope has had a history of instability at least since the construction of the AGS building (former Milliscreen Building) in the late 1980s when the toe of the former quarry slope was steepened, daylighting the slope parallel planar joint set (Beca Stevens, 1990). Recent qualitative rock fall assessments for this slope (Beca, 2019) indicated further rockfall at the site to be ‘likely’ to ‘almost certain’, putting the slope at moderate to high risk from future rockfall, and therefore requiring a remedial solution to reduce that risk.

A geotechnical desktop study was carried out in May 2020 for the SMF project (Connect Water 2020), identifying the rockfall hazard from the west facing slope adjacent to the AGS Building as presenting the greatest risk to the proposed development of this site.

Following the desktop study geological mapping of the cut slope was undertaken to provide a ground model for the slope stabilisation design. This work included manual measurements of rock defects at isolated outcrops and along eight sections of the cut slopes surrounding the site. The manually measured data were supplemented by defect measurements obtained from a point cloud of the southern and eastern cut slopes. The measurements from the point cloud provided data for elevated areas which could otherwise not be reached on foot. The point cloud was derived from a laser scan of the site. For detailed findings of the recent investigations prepared by Connect Water for Wellington Water Limited refer to Appendix A.

9 Construction Considerations

9.1 Drainage and Unsuitable Materials

To design for localised flooding and adequate drainage in response to rainfall, a detailed survey and underground service location assessment is required. Some removal of unsuitable soils (e.g.: non-engineered fill) is likely to be required when forming the final building engineering fill platform.

9.2 Foundation Excavations

The greywacke at this site is slightly to moderately weathered and due to the strength of the greywacke, the rippability of the greywacke should be considered as light-weight excavators may not be able to rip through the rock.

For deep excavations (e.g., sumps etc.), excavation using large diameter boring equipment such as those typically used for bored piles may be a suitable construction option. During construction, at each deep excavation location, predrilling should be carried out to identify the quality of the rock.

9.3 Conceptual Slope Stabilisation Design

9.3.1 Geotechnical Interpretation of Existing Slopes

Previous instabilities (slope movement and rockfall) and potential for future instabilities have been identified on existing slopes. As such, the stabilisation of existing slopes near the proposed developments is required. Kinematic analyses have found wedge, planar and toppling failures to control slope stability along the rock cut slopes as set out in the Connect Water Geotechnical Interpretive report prepared for Wellington Water Limited in Appendix B. To maximise the available area for the SMF development, active slope stabilisation using rock anchors and mesh is preferred over passive measures such as rockfall barriers.

9.3.2 Geotechnical Interpretation of New Cut Slopes

The current proposed layout of the SMF development will require some of the existing slopes to be cut. A new cut is now proposed to the north of the site adjacent to Moa Point Access Road to create a platform for a number of buildings and potential site access.

The static and seismic stability of the slopes will need to be assessed as part of the design. The required factors of safety for the design are outlined in Table 2 below:

Table 2: Required Factors of Safety for Slope Stability Design

External stability factor	Long Term Factor of Safety Target	Short Term Factor of Safety Target	
		Construction	Seismic
Static stability	1.5	1.2	-
SLS Earthquake Loads	-	-	≤1.0 (Assess displacement)
ULS Earthquake Loads	-	-	≤1.0 (Assess displacement)

The slope stabilisation is proposed to comprise rock anchors and mesh to minimise the risk of future rockfall events impacting the new development. There will be ongoing frittering of the rock slope and clearance of rocks fragments and boulders will need to part of the regular maintenance of the SMF facility. Also, a landing catch area at the toe of rock cut slopes will be created to receive rock fragments and boulders during and after inclement weather or large storm events.

Additional geotechnical investigations are required at the location of the new cut to the north of the site, adjacent to Moa Point Access Road, which is proposed to create a platform for a number of buildings and potential site access, as the current ground investigation data does not cover this area.

9.3.3 Proposed Design Solution

The concept design of the slope stabilisation includes:

- Cleaning/scaling loose material and vegetation from the slope, and removal of the accumulated colluvial blanket on the lower part of the slope.
- Installing drilled and grouted rock anchors and mesh on the slope.
- If the rock mass is significantly weaker (or soils are encountered) in the less steeply sloping upper part of the slope it may be preferable to install a pattern of soil nails (in place of rock anchors). Weepholes may also be required.
- Where the rock mass is highly fractured, and there is a risk of smaller blocks of rock frittering from behind the mesh, matting could be placed between the slope and mesh. An alternative would be to cover such areas with shotcrete.
- To improve the visual impact of the slope treatment, where possible, vegetation could be reinstated on the upper (less steeply sloping) part of the cut slope.

Based on the defect data collected to date, preliminary analyses indicate that a rock anchor layout with horizontal and vertical spacing of between 1.5m and 2.0m would likely be adequate to stabilise the upper 2m of rock and to minimise the risk of future rockfalls. The exact anchor spacing and length, along with other details of the stabilisation design, including rock anchor and mesh type, and whether matting or shotcrete are to be used, will be determined during later design stages.

10 Conclusions and Recommendations

There are several natural hazards (flooding and slope stability) that could impact on the proposed SMF development. The assessment shows that *without mitigation* the rock cut slopes (slope stability) pose a moderate to high probability of affecting the proposed development.

The stabilisation of existing rock cut slopes near the proposed SMF development is required to minimise the risk of future rockfall events impacting the new development. Slope stabilisation is proposed to comprise typical construction measures, such as rock anchors and mesh. With the slope stabilisation measures in place, the rock cut slopes will pose a low risk to the SMF development.

11 References

AGS, 2007: *Practice Note Guidelines for Landslide Risk Management 2007*, prepared by the Australian Geomechanics Society (AGS), 42(3).

Barnes P.M, Nodder S.D, Woelz S, Orpin A.R 2018: *The structure and seismic potential of the Aotea and Evans Bay faults, Wellington, New Zealand*, New Zealand Journal of Geology and Geophysics, vol. 62, no.1, 46-71p.

Beca, 2019: *AGS Building Slope Stabilisation: Geotechnical Input to Detailed Design of Rockfall Barrier*, prepared for Wellington International Airport Limited (WIAL).

Beca 2021: *SMF Moa Point Project - Geotechnical Investigation Factual Report*, prepared for Wellington City Council, dated 29 October 2021.

Beca Steven, 1990. Geotechnical Investigation Proposed Sites A and B Wellington Sewage Treatment Plant.

Begg, J.G., Mazengarb, C., 1996: Geology of the Wellington area, scale 1:50 000. Institute of Geological & Nuclear Sciences geological map 22. 1 sheet + 128 p. Lower Hutt, New Zealand: Institute of Geological & Nuclear Sciences Limited.

Begg, J.G., and Johnston, M.R., 2000: Geology of the Wellington area. Institute of Geological & Nuclear Sciences 1:250 000 geological map 10. 1 sheet + 64p. Lower Hutt, New Zealand: Institute of Geological & Nuclear Sciences Limited.

Connect Water, 2020: *Sludge Minimisation Utilisation and Reclamation Facility: Geotechnical Desktop Study – Moa Point,* prepared for Wellington Water.

GNS Active Fault Database (2018). https://data.gns.cri.nz/af/

GNS Geological Web Map. https://data.gns.cri.nz/geology/

New Zealand Standard. (2016). NZS 1170.5: Structural Design Actions, Part 5: Earthquake Actions - New Zealand, Amendment 1.

A

Appendix A – Geotechnical Factual Report

Wellington Water Consultancy Panel

Connect Water

Sludge Minimisation Utilisation and Reclamation Facility

Geotechnical Desktop Study – Moa Point
May 2020

Wellington Water Consultancy Panel

Sludge Minimisation Utilisation and Reclamation Facility

Geotechnical Desktop Study – Moa Point

May 2020

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Contents

1 Introduction

Connect Water Ltd has been commissioned by Wellington Water to undertake a geotechnical desktop study for the Sludge Minimisation Utilisation and Reduction Facility ('SMURF') project at Moa Point, Wellington. This study focuses on one set of proposed site options, namely, to locate the SMURF at one of two sites identified at Moa Point, Wellington.

This geotechnical desktop study report collates available ground investigation data near the proposed locations of the SMURF facility, and presents preliminary assessments of the geotechnical hazards which may affect the proposed development.

2 Site Description

The site is located adjacent the Moa Point Wastewater Treatment Plant (MPWWTP), near the intersection between Moa Point Road and Stewart Duff Drive. Moa Point is located at the south-west side of Miramar Peninsula, south of Wellington International Airport Ltd (WIAL) and the suburb of Strathmore Park.

There are two potential sites for the proposed SMURF development, one comprising the area occupied by the DHL Express and Aviation Ground Services (AGS) buildings (downslope and west of the MPWWTP) [Option 1], and the other on part of the Miramar Golf Course at the northern side of MPWWTP (Option 2). The site locations are indicated in Figure 1 below.

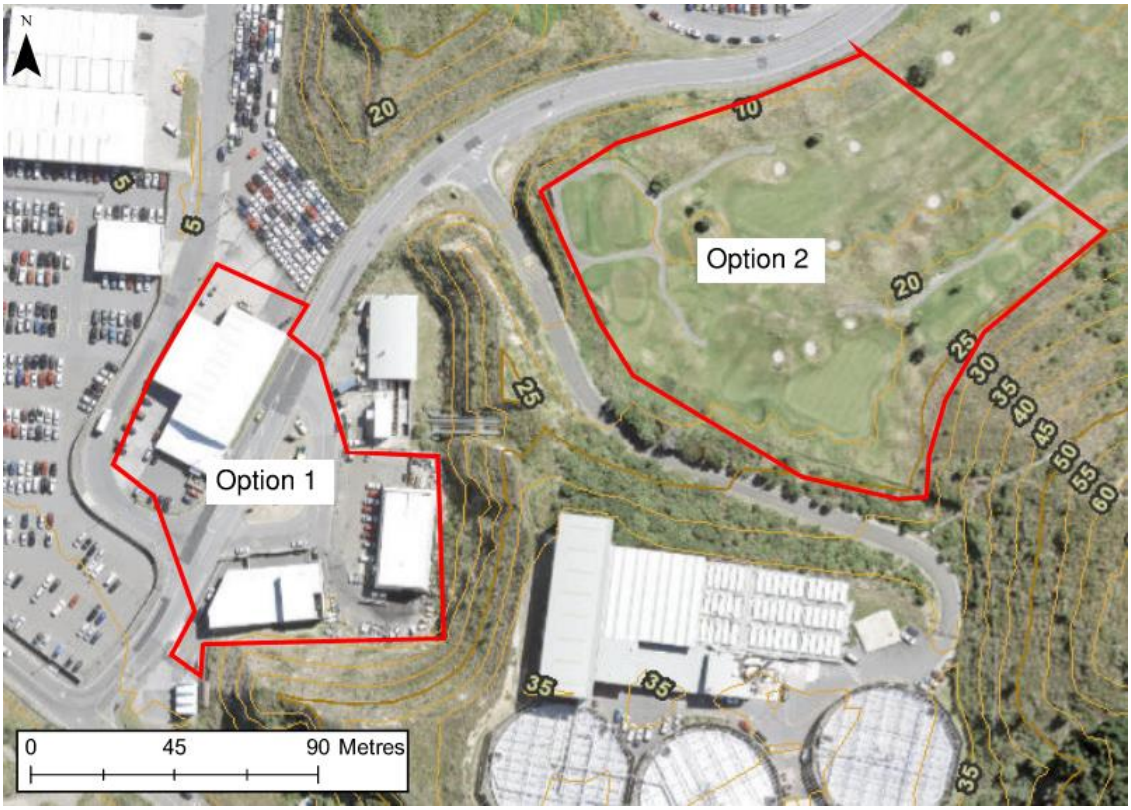

Figure 1: Site Option Location

Option 1 is a flat parcel of land straddling Stewart Duff Drive, immediately north of Moa Point Road and about 130m north of the coastline. The site is about 5m in elevation (metres above mean sea level, Wellington 1953), located at the toe of an unstable west facing slope of about 60° to 70° about 30m high, with the lower slope (debris fan) at about 35° to 40°. The slope curves around towards the southern side of the site and the MPWWTP sits at its crest. Option 1 is surrounded by WIAL carparking to the west and north.

Option 2 is north of the access road to the MPWWTP, comprising an undulating piece of land ranging from 10m to 20m elevation, sloping at about 6° and rising toward the south. The site is located at the toe of a northwest facing slope of about 20° to 30° (the slope crest is in a residential area at about 80m elevation, outside the site extent). The MPWWTP access road is in a rock cutting at the intersection with Stewart Duff Drive, with batter slopes of about 40° to 50°. The north side of the cutting is just beyond the boundary of Option 2. The access road curves toward the southeast, rising across a north facing slope. The slope below the access road, and meeting with Option 2 is about 20°, and covered with trees near the road shoulder.

Historical aerial photographs (with dates ranging from 1938 to 1980) suggest **Option 1** was formerly a rocky peninsula which was quarried from as early as 1938 through to at least the 1950s as part of the airport construction. It can be seen from these photographs that the natural west-facing slope to the east of **Option 1** was less steep in 1938, compared with the unstable former quarry slope in the present.

The AGS building at the eastern side of **Option 1** was built in 1988 - 1989 as the Milliscreen Building for sewage treatment, which was constructed to be a temporary structure. Earthworks included widening of the building platform by excavation of the quarry slope toe, which steepened the lower 10m height of the slope. Based on an historical photograph taken during construction of the MPWWTP, a landslip occurred not long after the excavation.

The historical aerial photographs suggest the area of **Option 2** was largely undisturbed until sometime between 1954 and 1980 when it was developed to be part of the Miramar Links Golf Club.

3 Geology

The published geological maps (Begg and Mazengarb, 1996; Begg & Johnston, 2000) shows both **Option 1** and **Option 2** to be underlain by greywacke rock of the Rakaia Terrane (Wellington Greywacke). Wellington greywacke consists of a fine-grained sandstone with variable amounts of interbedded mudstone (argillite), and is typically extensively faulted, tilted and folded, with very closely to closely spaced joints.

4 Previous Investigations

Previous geotechnical investigations have been documented in several reports, including:

- Beca Stevens, 1990: Geotechnical Investigation Proposed Sites A and B Wellington Sewage Treatment Plant.
  - The investigation included 3 machine boreholes near the edges of **Option 2**, drilled to depths of up to 20m, and 4 test pits in a similar area, excavated up to 3.3m depth. The investigation also has 3 boreholes
- Beca Carter Hollings & Ferner Ltd, 2004: WIAL RESA – South End Geotechnical Investigations.
- Included one test pit about 100m west of **Option 1**, excavated to a depth of 2.2m.

- Beca, 2018: WIAL Aviation Ground Services Building Slope – Preliminary Geotechnical Desktop Study Report.
- Included a site walkover visit to inspect the slope east of the AGS building) and surface feature logging.
- Beca, 2019: AGS building Slope Stabilisation: Geotechnical Input to Detailed Design of Rockfall Barrier
- A follow-up report to the AGS desk study including rockfall modelling and slope stabilisation options recommendations.

Approximate locations of the available historical investigations are as shown in Figure 2 below.

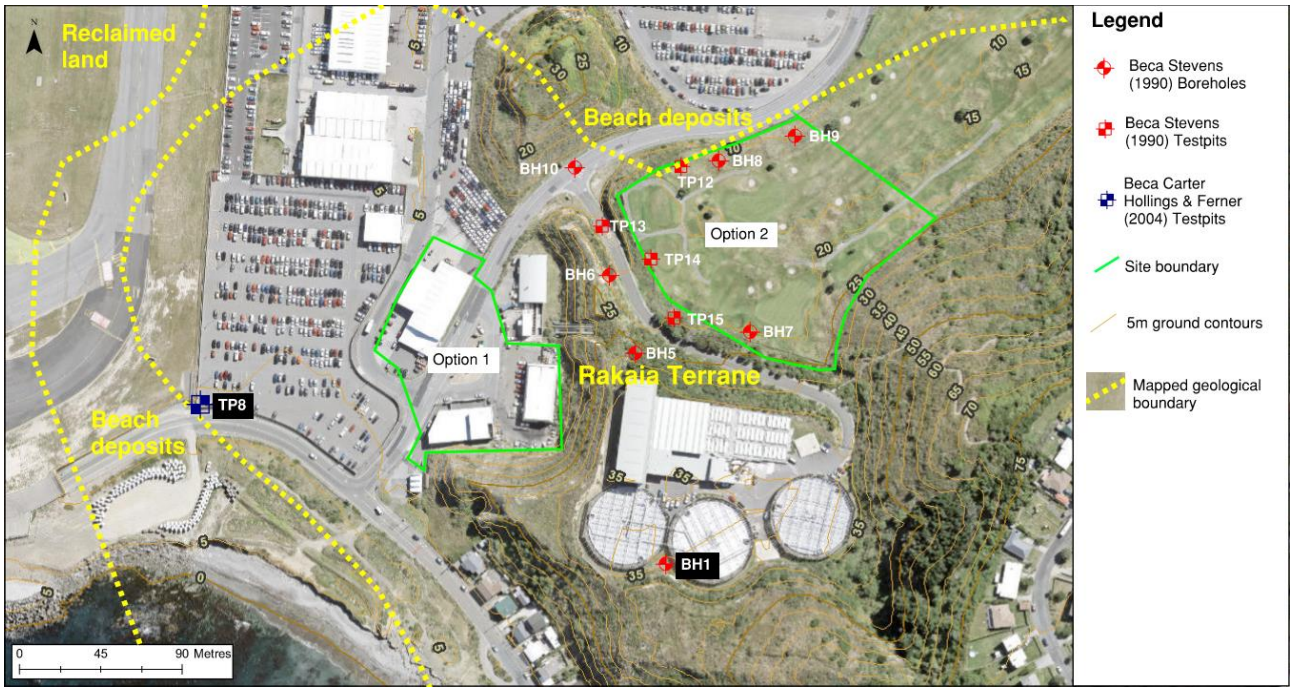

Figure 2: Location of historical investigations

5 Anticipated Soil Profile

As rock can be seen outcropping at ground level east of the AGS building, the eastern half of site **Option 1** is expected to be underlain by a shallow thickness of hardfill (associated with the asphalt pavement), overlying *in-situ* greywacke rock. Historical aerial photographs suggest the entirety of site **Option 1** is within a former quarry, though the portion of the site west of Stewart Duff Drive could potentially be underlain by a greater thickness of fill over *in-situ* greywacke rock, depending on the finished level of the quarry.

Option 2 is expected to be underlain by variable thickness of sand (and possibly fill), overlying *in-situ* greywacke rock. The report by Beca Stevens (1990) inferred the extent of soil and rock fill to be covering the site and refuse fill present in the southern quarter of the site. The soil profile across the site varies as follows:

- Investigations at the north of the site (BH8,9) encountered 13m to 16m of medium dense sand with minor gravel overlying thickly bedded medium dense to very dense sand with minor gravel and silt to at least the depth investigated (up to 20.45m below ground). Less dense sand layers

appear to be marine deposits. In general, the thickness of sand appears to increase toward the north.

- Investigations in the hill to the **south** (BH7) encountered 4m of sand fill with minor gravel, cobbles, and boulders overlying 4m of medium dense sand overlying silty gravel, cobbles and boulders. Below this completely to moderately weathered greywacke rock was encountered.
- Investigations in the **west** of the site (TP12-15) encountered a 0.3m to 1.0m thick layer of silty sandy gravel fill with some refuse (rusty iron and glass) overlying sand of about 1.5m to an unknown thickness. Below the sand *in-situ* completely weathered greywacke rock was encountered.
- There are no geotechnical investigations available for the eastern area of the Option 2 site.

6 Groundwater

No groundwater data were available for site **Option 1**, but the groundwater is expected to approximate sea level and be tidal due to the proximity of the site to the sea (i.e. within about 5m depth based on the site elevation, at or just above 0m RL).

Groundwater information for site **Option 2** include piezometers installed during the Beca Stevens (1990) work and monitored at that time. These indicate groundwater follow the contour of the ground, typically at depths of between 5m to 7m below ground (or between RL 4m and RL 14m in terms of the Wellington 1953 datum).

7 Geotechnical Hazards

7.1 Fault Rupture

The nearest fault to both site Options 1 and 2 is the Evans Bay Fault, which runs N-S through Evans Bay, about 1km west of the sites. This fault is considered 'active'; there is understood to be indirect evidence (displacement of sediments) suggesting there has been late Quaternary (last 500 thousand years to 1 million years) displacement along it (Begg and Mazengarb, 1996). Recent studies by Barnes et al (2018) estimate the fault has had one sea-floor rupturing earthquake in the past 10,000 years and is capable of generating earthquakes of magnitude (Mw) > 7. However, there are no published rupture characteristics for this fault.

As no active faults are mapped through either site the risk of direct fault rupture is assessed to be low.

7.2 Liquefaction and Cyclic Softening

Loose saturated sandy soils can be subject to significant strength loss under strong seismic shaking due to a phenomenon known as liquefaction. Liquefaction can have a number of significant effects where it occurs, including large lateral displacements affecting coastal or river bank slopes (termed lateral spreading), post liquefaction settlements (due to the densification of the affected sandy layers and loss of material to the surface) and potentially large and uneven settlement of shallow founded structures underlain by liquefiable soils.

Soft clayey soils can also lose strength due to a similar phenomenon known as cyclic softening. Cyclic softening is a liquefaction related phenomenon that occurs where cohesive soils are sheared during strong earthquake shaking. Cyclic softening can cause a significant strength loss in sensitive soils and may result in a number of liquefaction-like consequences including slope instability, building settlement or tilting.

The Greater Wellington Regional Council (GWRC) hazards data (available through their online GIS maps) indicates that there is no risk for liquefaction at the **Option 1** site. This is consistent with the anticipated soil profile – *in-situ* rock being near to the surface.

The GWRC hazards data for **Option 2** site indicates that there is low risk of liquefaction for soils to underlie the north-west corner. Low risk by the GWRC definition is defined as minor liquefaction damage occurring at MM 10 in the New Zealand Modified Mercalli intensity scale.

Based on the anticipated groundwater level, and available geotechnical investigation data (including 3 boreholes), there are at least 20 metres of sand and gravel of variable density, which may pose a liquefaction risk for a larger area of the **Option 2** site.

7.3 Lateral Spreading

Unsaturated soils above the groundwater table are assumed not to be susceptible to liquefaction. However, if liquefaction occurs at shallow depth in a saturated soil, the overlying unsaturated soil may move toward a free face or over gently sloping ground in a semi-intact fashion; this process is known as lateral spreading. Rupturing of the ground will tend to occur at the crest of the spreading movement, and compression at the toe of the movement.

The risk of lateral spreading is expected to be low at **Option 2** as the liquefaction risk is expected to be low to medium. Should lateral spreading occur, it is expected to flow north, the same direction as the gentle slope in the site.

It is expected that there is no risk of lateral spreading at **Option 1** as there is no liquefaction risk.

7.4 Tsunami

Tsunami are known to have affected Wellington Harbour in the past, including one 2.5 m high wave recorded at Lambton Quay following the 1855 Wairarapa earthquake (GeoEnvironmental Consultants, 2001).

The Institute of Geological and Nuclear Sciences (GNS) has prepared a report (Leonard et al, 2008) for Greater Wellington Regional Council (GWRC) presenting the inundation hazard. The modelling used a probabilistic tsunami height with a 500-year return period from regional and distant sources, and a probabilistic tsunami height with a 2500-year return period from all sources. This work has been used to define three zones for tsunami evacuation (yellow, orange and red - corresponding to increasing threat levels):

- The red (shore exclusion) zone, can encompass areas subject to inundation from wave heights with a 1% annual exceedance probability (i.e. 100-yr return period) from all sources (local, regional and distant).
- The orange zone was defined using probabilistic wave heights with a 0.2% AEP (i.e. 500-yr return period) from regional and distant sources.
- The yellow zone was defined using probabilistic wave heights with a 0.04% AEP (i.e. 2500-yr return period) from all possible sources and corresponds to the maximum credible event.

The evacuation zones described above are included in the GWRC GIS system. **Option 1** is located at the boundary between the orange and yellow zones and **Option 2** within the yellow zone.

The latest information on the tsunami hazard for New Zealand is presented in a pair of GNS reports (Power, 2013a,b), estimating that for Wellington a tsunami will reach a height of 6.2 m (50th percentile) above the sea level at the south coast about every 500 years on average (the 16th and 84th percentile heights are 5.3 and 7.1 m respectively). Note these are the modelled at-the-coast wave heights, the actual run-up or inundation will vary depending on topography. The assessment considered tsunami from all sources with (probabilistically) the majority of the hazard coming from near shore sources.

7.5 Flooding

The GWRC flood hazard map indicates both sites (Option 1 and Option 2) are not prone to flooding. However, the WCC flood zones map show potential for both **Option 1** site and **Option 2** to have localised flooding in a 1 in 100-year storm event (1 in 100-year annual return interval + 20% climate change intensity) and are assigned a flood hazard Level 1 which corresponds to a low risk.

7.6 Slope Stability

The GWRC GIS emergency management map gives slope failure risk ratings ranging from 1 - low, to 5 - high (largely based on average slope angles).

The slopes to the east/south of **Option 1** (east of the AGS building) is mapped as having a slope stability risk rating of 5 (high). The Beca (2018) report for the AGS building noted the *in-situ* greywacke rock of this former quarry slope to have closely to very closely (20-200mm) spaced and often persistent defects (several metres in length). A dominant planar joint set near parallel to the slope face (60°-70°) daylights in the west-facing slope. Rock slabs undergo planar/translation sliding along these joints, breaking up into cobbles and boulders up to 0.5m downslope, forming a debris fan. Some other joints intersect the main slope-parallel set, forming wedge failures. Most of the instability is in the centre of the cut area, the slopes to the north and south ends of the cut appear relatively stable.

This rock cut slope has had a history of instability at least since the construction of the AGS building (former Milliscreen Building) in the late 1980s when the toe of the former quarry slope was cut steeper, daylighting the slope parallel planar joint set (Beca Stevens, 1990). Recent qualitative rock fall assessments for this slope (Beca, 2019) indicated the likelihood of further rockfall at the site to be 'likely' to 'almost certain', putting the slope at moderate to high risk from future rockfall, and therefore requiring a remedial solution to reduce that risk. Previous measures to manage rockfall at the site have including scaling by an abseiling contractor. The Beca (2019) report recommended a rockfall protection barrier be installed to manage rockfall at the site.

The area of **Option 1** west of Stewart Duff Drive is at low risk of slope instability as it is some distance from any rock cut slopes.

The slope south-east of **Option 2** is mapped with a risk rating of 2-3 (low to moderate). The slope northwest of **Option 2** also has a risk rating of 2-3 (low to moderate). The slope southwest of **Option 2** does not have a given risk rating. **Option 2** is at some risk from slope instability, and the hazard could increase if any proposed structures are sited too close to the slope toe, placing it at risk of rockfall or a slip impacting the structure.

8 Conclusions

A summary of the site conditions, and qualitative assessments of the geotechnical hazards and design considerations for the two sites is provided below:

Table 8-1: Summary of Option 1 and Option 2

Item	Option 1	Option 2
Mapped geology	Greywacke rock	Greywacke rock
Anticipated Soil Profile	Greywacke rock at shallow depth	Variable thickness (estimated 5m to 20m) of fill and/or sand overlying greywacke rock
Groundwater	Estimated to be within 5m depth	Estimated to be between about 5m and 7m depth

Table 8-2: Summary of geotechnical hazards at Option 1 and Option 2

Geohazard	Option 1	Option 2
Fault rupture	Low	Low
Liquefaction and cyclic softening	None	Low to medium
Lateral spreading	None	Low
Tsunami	Moderate	Low
Flooding	Low	Low
Slope stability	Low (west) to high (east)	Moderate

9 Recommendations

For **Option 1,** the proposed structure could be founded directly on greywacke rock. The depth to rock should be confirmed by ground investigation. To design for localised flooding and adequate drainage provisions, a detailed survey and underground service location assessment would be required. If the eastern part of the site is developed care will need to be taken not to build too close to the slope due to the rockfall risk. This risk could be mitigated by installing rockfall protection and/or construct the eastern walls of the structures to withstand the impact of rockfall.

Similarly, a comprehensive ground investigation (to supplement the existing historical borehole and test pit data) is required for the **Option 2** site to determine the lateral variability and nature of the soils, depth to *in-situ* rock and liquefaction susceptivity.

In addition, consideration must be given to locating proposed structures away from the toe of the rock slopes. Rock slope assessment and remedial design should be undertaken for any slope modifications.

Removal of unsuitable soils (e.g. non-engineered fill) is likely to be required to form a suitable building platform, and ground improvements are likely to be required to mitigation liquefaction induced settlements.

10 Applicability

This report has been prepared by Connect Water on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which Connect Water has not given its prior written consent, is at that person's own risk.

Should you be in any doubt as to the applicability of this report and/or its recommendations for the proposed development as described herein, and/or encounter materials on site that differ from those described herein, it is essential that you discuss these issues with the authors before proceeding with any work based on this document.

11 References

Begg, J.G., Mazengarb, C., 1996: Geology of the Wellington area, scale 1:50 000. Institute of Geological & Nuclear Sciences geological map 22. 1 sheet + 128 p. Lower Hutt, New Zealand: Institute of Geological & Nuclear Sciences Limited.

Begg, J.G.; Johnston, M.R. (compilers) 2000: Geology of the Wellington area: scale 1:250,000. Lower Hutt: Institute of Geological & Nuclear Sciences. Institute of Geological & Nuclear Sciences 1:250,000 geological map 10. 64 p. + 1 folded map

GeoEnvironmental Consultants, 2001: *Wellington Regional Tsunami Hazard Scoping Project*. Report prepared for Wellington Regional Council.

Power, W.L. (compiler), 2013a: *Review of Tsunami Hazard in New Zealand (2013 update),* GNS Science Consultancy Report 2013/131. 222 p.

Power, W.L., 2013b. Tsunami hazard curves and deaggregation plots for 20km coastal sections, derived from the 2013 National Tsunami Hazard Model, GNS Science Report 2013/59. 547 p.

Barnes P.M, Nodder S.D, Woelz S, Orpin A.R 2019: *The structure and seismic potential of the Aotea and Evans Bay faults, Wellington, New Zealand*, New Zealand Journal of Geology and Geophysics, vol. 62, no.1, 46-71p.

Beca Carter Hollings & Ferner Ltd, 2004: WIAL RESA – South End Geotechnical Investigations.

Beca Stevens, 1990: Geotechnical Investigation Proposed Sites A and B Wellington Sewage Treatment Plant.

Beca, 2018: WIAL Aviation Ground Services Building Slope – Preliminary Geotechnical Desktop Study Report.

Beca, 2019: AGS building Slope Stabilisation: Geotechnical Input to Detailed Design of Rockfall Barrier

GNS Science, Active Faults Database (http://data.gns.cri.nz/af/index.html)

Greater Wellington Regional Council GIS viewer (http://mapping.gw.govt.nz/gwrc/)

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B

Appendix B – Geotechnical Interpretive Report

Wellington Water Consultancy Panel

Connect Water

Wellington Sludge Minimisation Facility (SMF)

Geotechnical Interpretive Report
November 2020

Wellington Water Consultancy Panel

Wellington Sludge Minimisation Facility (SMF)

Geotechnical Interpretive Report

November 2020

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Contents

Abbreviations

Abbreviation	Full name
AGS Building	Aviation Ground Services Building
DCLS	Damage control limit state
GSI	Geological Strength Index
mRL	Metres reduced level
PGA	Peak ground acceleration
SMF	Sludge Minimisation Facility
SLS	Serviceability limit state
UCS	Unconfined compressive strength
ULS	Ultimate limit state
WCC	Wellington City Council
WWTP	Wastewater treatment plant

1 Introduction

The Wellington region's wastewater is currently managed through the operation of four Wastewater Treatment Plants (WWTPs), with disposal of the collected sludge into three landfills. All sludge from Wellington City's Moa Point and Western WWTPs is currently dewatered at the Carey's Gully sludge dewatering plant (south of the Southern Landfill) and then disposed of in the Southern Landfill.

Wellington City Council (WCC) requires a change in the management of the sludge produced from its wastewater treatment plants. The change needs to enable the management of the sludge to be 'de-coupled' from the existing disposal to the Southern Landfill and enable WCC to pursue other options for disposing of, or otherwise utilising the sludge.

To achieve this change, WCC wish to establish a new Sludge Minimisation Facility (SMF). The site selected for the SMF is at the toe of the slope immediately below (west of) the current Moa Point WWTP. No new cut slopes, or additional cutting of existing slopes are required for the proposed developments.

As rockfalls are known to have occurred on the existing slope immediately below the Moa Point WWTP, geological mapping and analyses of the cut slopes surrounding the site were required to determine which slopes will need to be stabilised as part of the construction of the new facility.

This report presents the interpretation of the field data, including a ground model for the site, slope stability assessments and conceptual stabilisation designs, as well as construction considerations. Detailed design of stabilisation works is not covered in this report.

2 Site Description and Proposed Developments

2.1 Site Location and Description

The site is east of Lyall Bay, near Moa Point at the southwestern end of the Miramar Peninsula, southeast of Wellington International Airport (Figure 1, refer to Appendix A for a detailed site plan). It covers the properties between 141 and 145 Stewart Duff Drive, Kilbirnie.

The proposed facility is located at the foot of a steep former quarry slope, immediately below the Moa Point WWTP (see 'area of proposed extension' in Figure 1). The rock slope below Moa Point is inclined about 60° to 70° to the west, while the lower part of the slope (debris fan) slopes at about 35° to 40° to the west. The slopes at the southern end of the site are generally inclined at about 40° to the north. However, near the toe the slopes have been cut steeper, between 60-80°.

The area at the toe of the slope is on flat ground (elevation about 5-6m above mean sea level, Wellington 1953 Datum). With the exception of the grassed area behind the pump station the site is paved.

Figure 1. Location of the site below the existing Moa Point WWTP, southeast of Wellington Airport. The inset map shows the site location (red square) in Wellington.

2.2 Historical Site Use

Historical aerial photographs indicate the site was formerly a rocky peninsula which was quarried from as early as 1938 through to the 1950s as part of the Wellington International Airport construction. The west facing slope is the former quarry slope, however in the late 1980s the construction of the AGS Building (which was formerly the Moa Point WWTP Milliscreen Building) resulted in steepening of the lower 10m of this slope. Photographs from that time suggest a landslip occurred shortly after construction, and instability appears to have been ongoing with debris periodically accumulating at the slope toe behind the AGS Building.

2.3 Proposed Developments

The SMF is proposed to be located in a relatively flat-lying site between Wellington International Airport and the Moa Point Wastewater Treatment Plant. The site is currently occupied by the pump station for the Moa Point WWTP to the north, the Aviation Ground Services (AGS) Building in the centre-east, and the Cyclotek Building to the south.

The proposed SMF consists of several structures including process and plant buildings, as well as digester and digestate tanks. The development of the facility would require the demolition of the Cyclotek and AGS buildings. The currently proposed conceptual layout is shown in Figure 2.

No new cut slopes or further cutting of existing slopes are required for the currently proposed layout of the SMF development.

It is understood that the SMF developments are to be designed to a design life of 50 years, and importance level 3 (in accordance with NZS1170).

Figure 2. Conceptual SMF site layout (as at 22/09/2020).

3 Site Investigations

3.1 Previous Investigations

3.1.1 Beca Steven (1990)

In 1989 Beca Steven (1990) undertook ground investigations for the (then proposed) WWTP at Moa Point, immediately upslope (east) of the AGS Building, at the Miramar Golf Course and in the area surrounding the current Moa Point WWTP. Those investigations included machine boreholes, test pits, laboratory analyses, as well as geophysical (seismic refraction) surveys to interpolate ground conditions between the bores and pits. The locations of the test pits and boreholes are shown on the site plan in Appendix A. The Beca Steven (1990) investigation data is appended in the Geotechnical Factual Report (Connect Water, 2020b).

The boreholes identified a generalised profile of:

- Sand (both cover for landfill refuse, and natural aeolian deposits),
- Refuse (landfill),
- Soil and rock fill,
- Colluvium (typically in gullies),
- In-situ completely to highly weathered greywacke rock, and
- In-situ moderately weathered greywacke rock.

Boreholes nearest the slope (BH05, BH06; see Appendix A for locations) included sand and fill/colluvium overlying in-situ rock at about 20m to 22mRL. It is noted that these investigations were undertaken prior to construction of the WWTP, which included significant cutting for the access road to the WWTP and to construct the platform where the WWTP is located. As such, some surficial soils and rock have likely been removed since the investigations were undertaken.

3.1.2 Beca (2019)

In 2019 Wellington International Airport requested that rockfall assessments be undertaken for the eastern slope behind the AGS Building. The rockfall assessments (using the 2007 AGS guidelines) indicated that without remediation further rockfalls at the site are “likely” to “almost certain”, putting the building at “moderate” to “high” risk (Beca, 2019). Based on field observations and 2-dimensional rockfall modelling, Beca (2019) recommended remediation of the hazard using passive rockfall protection barriers to minimise the risk of rockfall striking the AGS Building.

3.2 Recent Investigations

A geotechnical desktop study was carried out in May 2020 for the SMF project (Connect Water 2020a), identifying the rockfall hazard from the west facing slope adjacent the AGS Building as presenting the greatest risk to the proposed development of this site.

Following the desktop study geological mapping of the cut slope was undertaken to provide a ground model for the slope stabilisation design. This work included manual measurements of rock defects at isolated outcrops and along 8 sections of the cut slopes surrounding the site. The manually measured data were supplemented by defect measurements obtained from a point cloud of the southern and eastern cut slopes. The measurements from the point cloud provided data for elevated areas which could otherwise not be reached on foot. The point cloud was derived from a laser scan of the site. For detailed findings of the recent investigations refer to Connect Water (2020b).

4 Ground Model

4.1 Published Geology

The published geological maps (Begg and Mazengarb, 1996; Begg and Johnston, 2000) indicate the site is underlain by greywacke rock (Rakaia Terrane; Triassic to Jurassic in age). Rakaia Terrane greywacke

consists of variably weathered sandstone, interbedded with varying amounts of argillite. It is extensively faulted, tilted and folded, commonly with very closely to closely spaced joints.

A strike and dip measurement on the geological map (Begg and Johnston, 2000) shows an overturned bedding to dip 77° to the southeast at the southern end of Moa Point (Figure 3a). Suneson (1993) also recorded strike and dip measurements indicating bedding to dip 84° to the west at Moa Point, and 82° to the northwest (overturned bedding) about halfway between Moa Point and the site (Figure 3b).

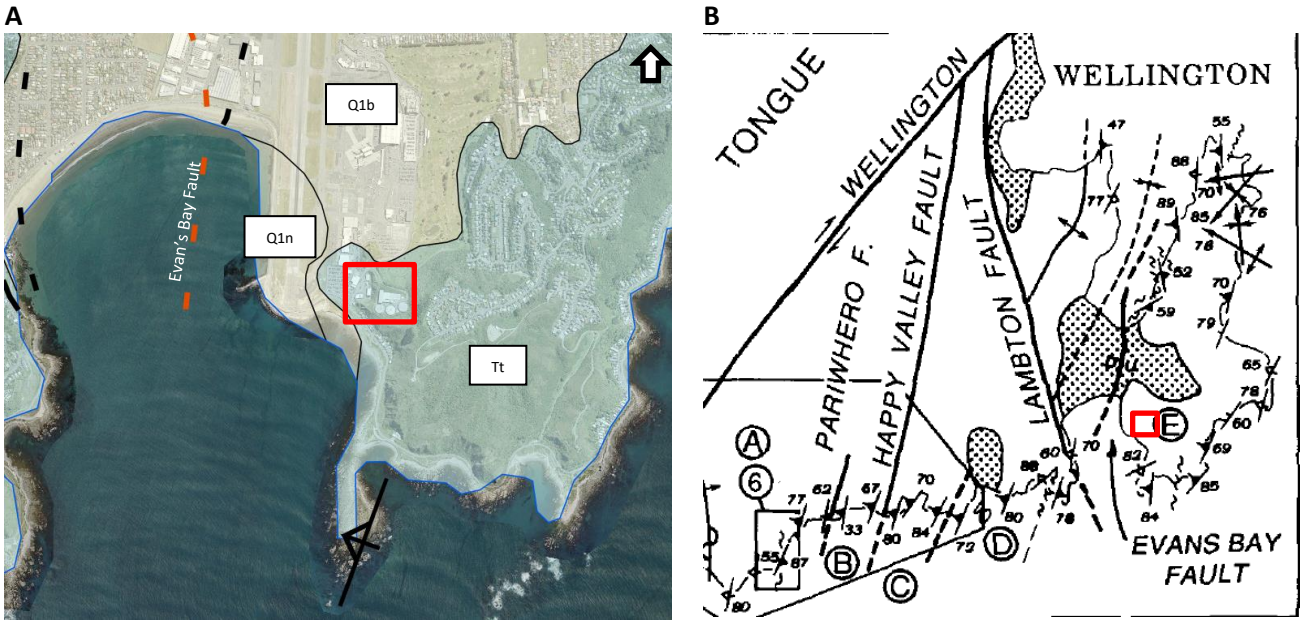


Figure 3. Geological maps of the area (A - Begg and Johnston, 2000; B - Suneson, 1993), with the approximate location of the site shown by the red square. Symbols: Q1n – reclaimed land; Q1b – Holocene beach deposits; Tt – Rakaia Terrane Greywacke

4.2 Ground Model

As the site is within a former quarry, the ground level is anticipated to be underlain by greywacke rock at very shallow depth.

Based on field mapping the in-situ greywacke sandstone exposed in the slopes was generally found to be moderately strong to strong and slightly to moderately weathered. The weathering of the greywacke appeared to increase toward the eastern slope, and with increasing height along the eastern slope. The exposed greywacke along Section 6 (see Appendix A) also appeared relatively more weathered. Defects were generally closely to very closely (20-200mm) spaced. The observed defect spacings and weathering pattern are broadly consistent with those observed in the boreholes drilled by Beca Steven (1990).

No specific strength testing (e.g. unconfined compressive strength, UCS) was undertaken as part of this work. However, a UCS test undertaken on a sample of moderately weathered greywacke from borehole BH3 (sample elevation 19.50mRL) by Beca Steven (1990) yielded an UCS of 25.7MPa.

Argillite beds were only observed at three discrete locations at Section 0, Section 1 and by an outcrop near Moa Point Road. Where observed, the argillite beds (<200mm thick) were sub-vertically interbedded with greywacke over a horizontal distance of 300-800mm. At the outcrop on Section 1 the argillite and greywacke beds were observed to be folded. Bedding orientations measured along the greywacke and

argillite contacts were found to be striking northeast-southwest, and dipping near vertically (85-89°) to the southeast. Strike and dip measurements on bedding are shown in red on the geological map in Appendix B.

Manual rock defect measurements from around the site, and defect measurements obtained from a point cloud of the southern and eastern cut slopes (see Appendix A for outline of the laser scan extent) were plotted on a stereonet in the software Dips (Rocscience Inc) to identify preferential orientations (Figure 4). Cluster analysis of the defect measurements show that the dominant set of defects ('Set 1') dip steeply to very steeply to the west-northwest. In the field, Set 1 defects were especially apparent along the eastern and south-eastern slopes, where they are (sub-)parallel to, and daylight in, the slope face (55°-70°). Along these slopes, the unfavourable angle of the persistent defects to the excavated slope appears to have caused rock slabs to undergo planar sliding along these joints, breaking up into cobbles and boulders (up to 900mm diameter, but predominantly <200mm diameter) downslope, forming a debris fan.

A second defect set ('Set 2') was also identified. These defects are subvertical, striking southeast-northwest. Combined with defects dipping steeply to very steeply to the northwest, some of the defects belonging to Set 2 were found to form wedge failures behind the Cyclotek Building.

The observations outlined above are presented on the geological map in Appendix B.

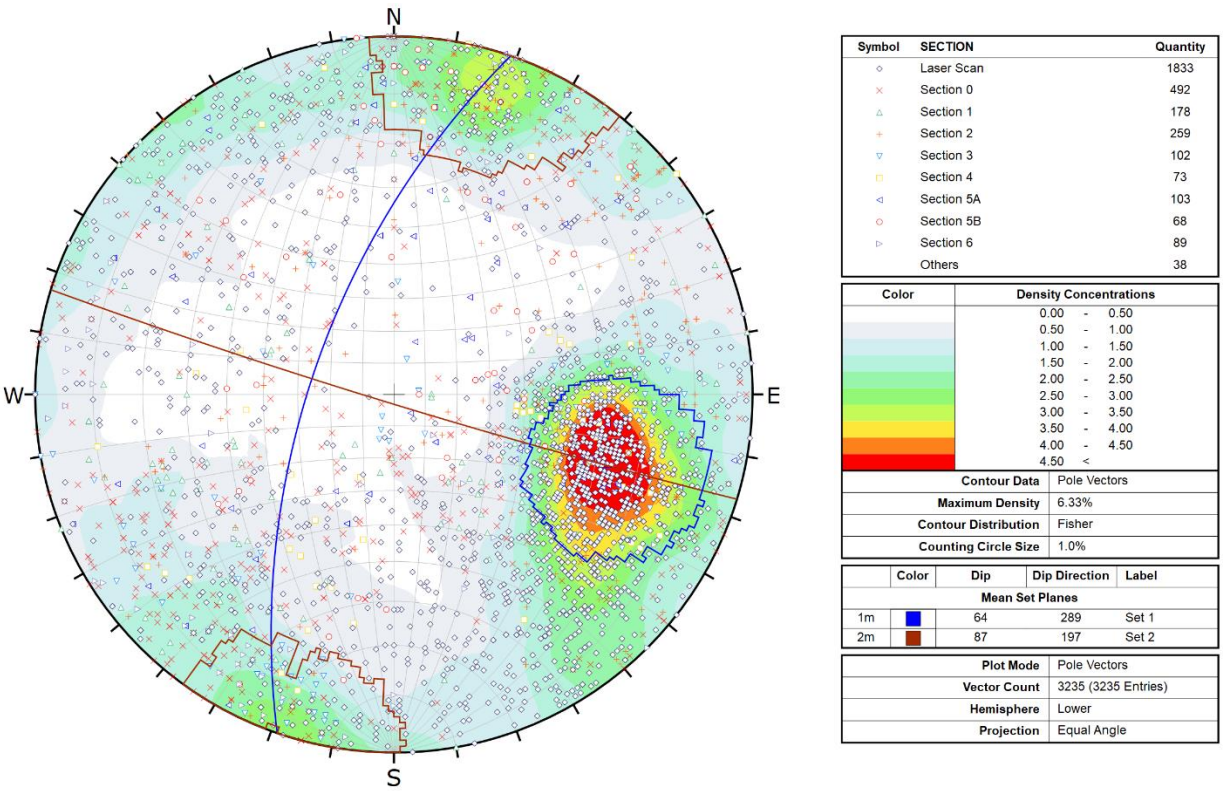


Figure 4. Stereonet showing all defect measurements taken at the site, as well as the two identified defect sets and their mean planes.

4.3 Geotechnical Parameters

Hoek-Brown strength parameters have been derived for the greywacke rock mass using existing laboratory data (Beca Steven, 1990), field mapping data (Connect Water, 2020b) and published articles.

The Geological Strength Index (GSI; Hoek and Marinos, 2000) is widely used to characterise the rock mass strength for jointed rocks. The GSI value is determined by plotting the geological structure and surface conditions of defects on a GSI chart. For this work the modified GSI chart for application to New Zealand greywacke (Read et al., 2000) was used. The estimated GSI range for the greywacke at the site is plotted on the chart in Figure 5.

The GSI is not applicable for parts of the eastern slope where stability is controlled by a dominant defect set which is orientated unfavourably to the dip of the slope (see Section 6.2). This is because any failures here are governed by the shear strength of the defects rather than the rock mass (Marinos et al., 2005).

Mohr-Coulomb parameters for were derived using the Hoek-Brown parameters and the software RocData.

The Hoek-Brown and Mohr-Coloumb parameters to be used for the slightly to moderately weathered greywacke in the geotechnical design are presented in Table 1.

Table 1. Hoek-Brown and Mohr-Coulomb parameters for the slightly to moderately weathered greywacke rock at the site.

Parameter	Symbol	Value Adopted	Source
Unit weight	γ	24.5 kN/m^3	» Laboratory test undertaken by Beca Steven (1990) on moderately weathered greywacke
Uniaxial compressive strength	σ_{ci}	25 MPa	» Based on a UCS test on moderately weathered greywacke by Beca Steven (1990), which yielded at 25 MPa
Hoek-Brown constant for rock material	m_i	12	» Modified m_i values for New Zealand greywacke proposed by Richards & Read (2007) and Read et al. (2000)
Modulus ratio	MR	350	» RocData default for greywacke
Geological Strength Index [1]	GSI	30-40 (~35)	» This study (see Figure 5) » Field mapping by Connect Water (2020b) » GSI chart with informal NZ greywacke classification classes (Read et al., 2000)
Effective cohesion [2]	c'	0.22 MPa	» This study, using RocData and a slope height of 30m
Effective friction angle [2]	φ'	46°	» This study, using RocData and a slope height of 30m

Notes:

» [1] Not applicable where stability is controlled by a dominant defect set (e.g. on the eastern slope)

» [2] Relevant to slope heights on the order of 30m.

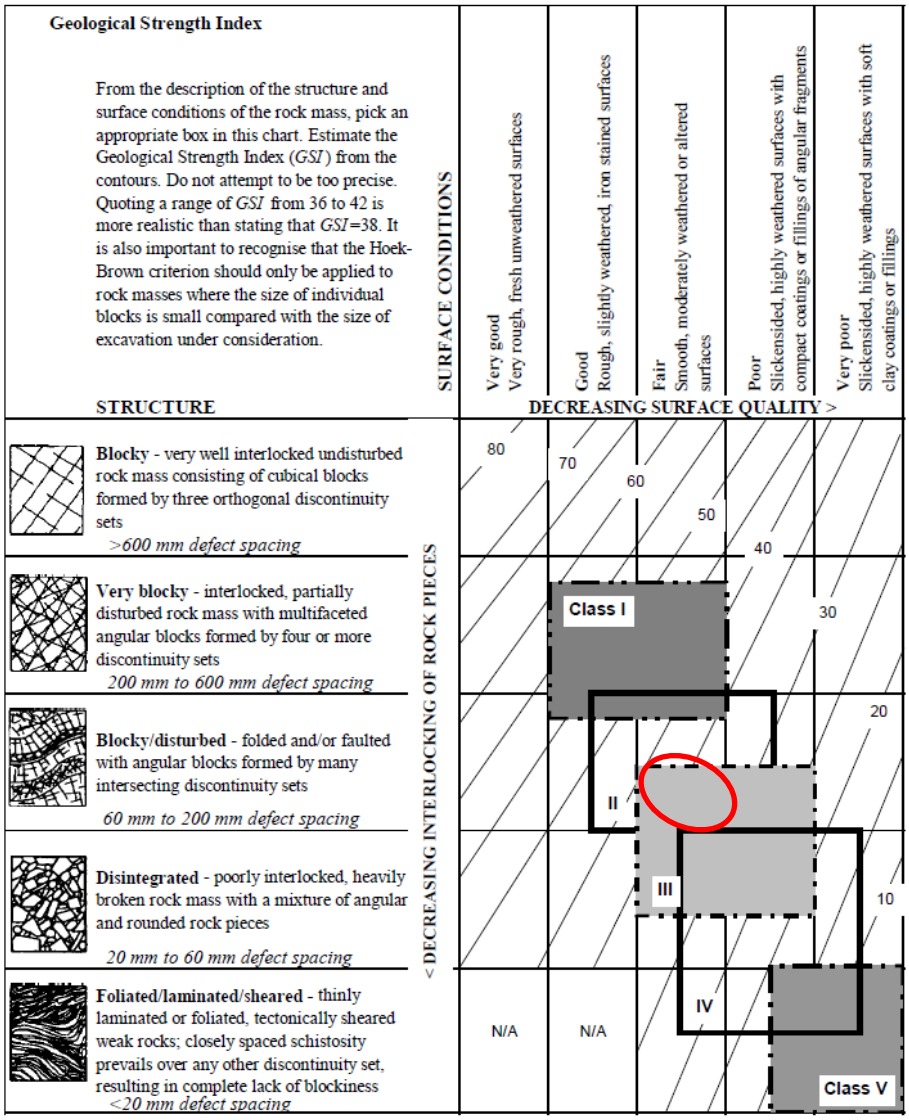


Figure 5. Geological Strength Index (GSI) with informal classes of New Zealand greywacke overlaid (Read et al., 2000). The red circle represents the estimates GSI range for the greywacke observed at the site.

4.4 Groundwater

No groundwater seepages were observed on the slopes during the field mapping. However, in boreholes BH5 and BH6, which were drilled above the eastern slope (see Appendix A for locations) groundwater was encountered at 16.4mRL and 4.2mRL, respectively (Beca Steven, 1990).

No groundwater measurements are available at the site of the proposed developments. However, based on the proximity of the site to the shoreline, groundwater is expected to be encountered within the upper 2-3m below ground level and is expected to be tidally influenced.

5 Seismic Assessment

5.1 Fault Rupture Hazard

The nearest identified active fault to the site is the north-south oriented Evans Bay Fault, about 1km to the west (Figure 3). Barnes et al (2018) estimate the fault has had one sea-floor rupturing earthquake in the past 10,000 years and is capable of generating earthquakes of magnitudes (Mw) >7. There are no published rupture characteristics available for this fault.

As no active faults are mapped through the site the risk of direct fault rupture is assessed to be low.

5.2 Site Subsoil Classification

The site is expected to be underlain by greywacke rock at very shallow depth. An unconfined compressive strength (UCS) test for moderately weathered greywacke rock at the WWTP site, undertaken by Beca Steven (1990), indicated a strength of about 25 MPa. As such, in accordance with NZS1170.5:2004, Site Subsoil Class B ('Rock') is recommended to be adopted for the site.

5.3 Seismic Design Loads

The design peak ground acceleration (PGA) for the Ultimate Limit State (ULS) and Serviceability Limit States (SLS) have been determined based on the Waka Kotahi NZ Transport Agency Bridge Manual (2018) and NZS1170.5:2004 (Table 2, Table 3) in accordance with the recommendations of NZGS Module 1 (2016).

Table 2. Derivation of seismic loading values

Design Life	Importance Level	Site Subsoil Class	Ch(t)	Z factor	R_u / R_s (BM)	R_u /R_{S1} (1170)	N(T,D)	$C_{0,1000}$
50 years	3	B	1.0	0.4	1.3 / 0.5	1.3 / 0.25	1.0	0.44

Notes:

- Ch(t) – Spectral shape factor
- Z factor – hazard factor
- R_u/R_s - Return period factor based on ULS/SLS
- N(T,D) - Near fault factor
- $C_{0,1000}$ - 1000 year return period PGA coefficient

We recommend that the seismic loadings outlined in Table 3 be used for geotechnical design. Note these may not be applicable for structural design.

Table 3. Seismic loading values recommended for design

Seismic Case	NZS1170.5:2004		Bridge Manual	
	PGA (g)	Earthquake Magnitude	PGA (g)	Earthquake Magnitude
ULS/ DCLS (1/1000)	0.52	7.5	0.44	7.10
Minor (1/100)	-	-	0.17	6.20
SLS1 (1/25)	0.10	7.5	-	-

6 Slope Stability Assessments

Based on the field mapping (Connect Water, 2020b) and ground model outlined in Section 4.2, the site has been divided into three sectors:

- Sector 1: Southern slopes
- Sector 2: Eastern and south-eastern slopes
- Sector 3: Northern slopes

For each sector kinematic analyses were undertaken to determine which failure mechanisms could affect slope stability. Analyses were undertaken by loading all defects measurements from the site (manual and point cloud derived; n = 3235) into the software Dips, using cluster analyses to derive defect sets (see Section 4.2), and then checking for possible planar, wedge and toppling failures arising from combinations of defects and the slope orientations. These analyses only account for the most likely instability modes which could arise due to the orientations of the preferential defect sets with respect to the slope angles. Smaller wedge, toppling or planar failures not related to the dominant defect sets may still occur.

The slope stability assessments for each of the sectors are summarised below. Stereonets and kinematic analyses are attached in Appendix C.

6.1 Sector 1: Southern Slopes

Sector 1 extends east from the western end of Section 0 to the western end of Section 2 (see Appendix B). The slope dip direction varies between 350° and 030°, and the slope dip along the manually measured sections generally ranged from 60-80°.

Kinematic analyses were undertaken for slope dip directions of 350°, 000° and 030°, with slope dips of 60°, 70° and 80°. The results indicate that toppling and wedge failures form the dominant potential failure mechanisms along this Sector. This is consistent with the wedge failures identified behind the Cyclotek Building (see Section 4.2). The results of the kinematic analyses are summarised in Table 4.

Table 4. Summary of kinematic slope stability analyses for Sector 1.

Approx. Slope Dip Direction	Control on Stability				Comments
	Planar[1]	Wedge	Flexural Toppling[1]	Direct Toppling[1]	
350°	No	**Yes**	**Yes**	Minor	» Planar: Minor (<6%) potential planar failures were identified, but not deemed critical. » Wedge: Wedge failures are possible, especially with increasing slope dip angles above 60°. » Flexural toppling: Flexural toppling failures are possible. » Direct toppling: No critical intersections for major direct toppling failures were identified, but oblique toppling failures are possible.
000°	No	**Yes**	**Yes**	Minor	» Planar: Minor (<6%) planar failures were identified, but not deemed critical. » Wedge: Critical wedge failures are possible and there is an increasing risk of critical wedge failures with increasing slope angles above 60°. » Flexural toppling: Flexural toppling failures are possible, with an increasing number of critical failures with increasing slope angles above 60°. » Direct toppling: No critical intersections for major direct toppling failures were identified, but oblique toppling failures are possible.
030°	No	No	**Yes**	Minor	» Planar: Minor (<6%) potential planar failures were identified, but not deemed critical. » Wedge: Minor (<6%) potential wedge failures were identified at ~80° slope angles, but not deemed critical. » Flexural toppling: Flexural toppling failures are possible, with an increasing number of critical failures with increasing slope angles above 60°. » Direct toppling: Minor critical intersections for direct toppling failures were identified, and oblique toppling failures are also possible.

Notes:

» [1] Lateral limits of 20° were used.

6.2 Sector 2: Eastern and South-Eastern Slopes

Sector 2 extends from the northern end of Section 5A south along the eastern slope and also includes the south-eastern slope along Section 2 (see Appendix B). The slope dip direction varies between 270-290° along the east facing slopes (i.e. Sections 5A, 4 and 3) to about 330-340° along Section 2. The slope dip along the manually measured sections generally ranged from 60-75°.

Kinematic analyses were undertaken for slope orientations of 270°, 290° and 340°, with slope dips of 60°, 70° and 75°. These analyses have confirmed the that the dominant failure mechanism on the eastern slope

is planar sliding due to the presence of persistent defects (Set 1) at unfavourable orientations with respect to the existing slope (as was suggested based on field mapping, see Section 4.2). Wedge failures also appear to have a significant control on slope stability, especially where the slope angle is greater than 60°. The results of the kinematic analyses are summarised in Table 5.

Table 5. Summary of kinematic slope stability analyses for Sector 2.

Approx. Slope Dip Direction	Control on Stability				Comments
	Planar[1]	Wedge	Flexural Toppling[1]	Direct Toppling[1]	
270°	**Yes**	**Yes**	No	No	» Planar: Critical planar failures are possible and there is an increasing risk of critical planar failures with increasing slope angles above 60°. » Wedge: Critical wedge failures are possible and there is an increasing risk of critical wedge failures with increasing slope angles above 60°. » Flexural toppling: Minor (<6%) potential flexural toppling failures were identified, but not deemed critical. » Direct toppling: Although critical base planes were identified, no critical intersections for major direct toppling failures were identified.
290°	**Yes**	**Yes**	No	No	» Planar: Critical planar failures are possible and there is an increasing risk of critical planar failures with increasing slope angles above 60°. » Wedge: Critical wedge failures are possible and there is an increasing risk of critical wedge failures with increasing slope angles above 60°. » Flexural toppling: Minor (<6%) potential flexural toppling failures were identified, but not deemed critical. » Direct toppling: Although critical base planes were identified, no critical intersections for major direct toppling failures were identified.
340°	Minor	**Yes**	No	Minor	» Planar: Minor planar failures are possible but are generally beyond the lateral limit of 20° from the slope dip direction. » Wedge: Critical wedge failures are possible and there is an increasing risk of critical wedge failures with increasing slope angles above 60°. » Flexural toppling: Minor (<6%) flexural toppling failures were identified, but not deemed critical. » Direct toppling: No critical intersections for major direct toppling failures were identified, but oblique toppling failures are possible.

Notes:

» [1] Lateral limits of 20° were used.

6.3 Sector 3: Northern Slopes

As no proposed developments are in close proximity to the northern slopes, no further analyses were undertaken. However, should this area be developed or utilised (e.g. for storage, parking or access) in the future, analyses will be required.

7 Conceptual Slope Stabilisation Design

Previous instabilities and potential for future instabilities have been identified on existing slopes. As such, the stabilisation of existing slopes near the proposed developments is required. In order to maximise the available area for the SMF development, active slope stabilisation using rock anchors and mesh is preferred over passive measures such as rockfall barriers.

It is noted that the currently proposed layout of the SMF development will **not** require the existing slopes to be cut any further, nor will any new cuts be required at the site. Should any additional or new cuts be required, further analyses will need to be undertaken and the conceptual slope stabilisation designs will need to be revised.

The proposed stabilisation measures for each sector are outlined below.

7.1 Sector 1: Southern Slopes

Kinematic analyses have found wedge and toppling failures to control slope stability along Sector 1. Stabilisation designs will have to be developed to address these potential failure mechanisms.

Stabilisation will likely only be required at selected locations near the base of slope, where the slope toe has been cut very steeply and where significant wedge or toppling failures are exposed. The locations, extent and details of the stabilisation design for Sector 1 are to be determined during later design stages.

7.2 Sector 2: Eastern and South-Eastern Slopes

Kinematic analyses and field mapping have found planar and wedge failures were found to control the slope stability along Sector 2. 'Surficial' (i.e. approximately upper 2m thickness) stabilisation measures are proposed to address these observed and potential future instabilities along the eastern slope and southeastern slopes. The slope stabilisation is proposed to comprise rock anchors and mesh to minimise the risk of future rockfall events impacting the new development.

The concept design of the slope stabilisation includes:

1. Cleaning/scaling loose material and vegetation from the slope, and removal of the accumulated colluvial blanket on the lower part of the slope (though not trimming the slope itself, as this could trigger further instability);
2. Installing drilled and grouted rock anchors and mesh on the slope;
3. If the rockmass is significantly weaker (or soils are encountered) in the less steeply sloping upper part of the slope it may be preferable to install a pattern of soil nails (in place of rock anchors). Weepholes may also be required.

4. Where the rockmass is highly fractured, and there is a risk of smaller blocks of rock frittering from behind the mesh, matting could be placed between the slope and mesh. An alternative would be to cover such areas with shotcrete.

5. To improve the visual impact of the slope treatment, where possible, vegetation could be reinstated on the upper (less steeply sloping) part of the cut slope.

Based on the defect data collected to date, preliminary analyses indicate that a rock anchor layout with horizontal and vertical spacing of between 1.5m and 2.0m would likely be adequate to stabilise the upper 2m of rock and to minimise the risk of future rockfalls. The exact anchor spacing and length, along with other details of the stabilisation design, including rock anchor and mesh type, and whether matting or shotcrete are to be used, will be determined during later design stages.

7.3 Sector 3: Northern Slopes

As no developments are currently proposed in close proximity to the toe of the slopes in the northern sector, no slope stabilisation measures are proposed here. However, should this area be developed or utilised (e.g. for storage, parking or access) in the future, further consideration of the slope stabilisation will be required.

8 Foundation Considerations

8.1 Bearing capacity

Given the historical use of the site as a quarry, greywacke rock is expected at very shallow depths below ground level. As such, it is assumed that the structures will be founded into slightly to moderately weathered greywacke rock.

We recommend a geotechnical ultimate bearing capacity of 1MPa for structures founded within the slightly to moderately weathered greywacke rock. For limit state structural design (with code factored structural loads), a strength reduction factor of 0.5 shall be applied to this value.

The depth of foundations required will depend on the structural load demand of each structure and will be confirmed during the design phase.

Once excavated, and prior to the construction of the foundations, the founding rock should be inspected by a geotechnical engineer or engineering geologist to identify any defects or shear zones which could adversely affect the bearing capacity of the founding rock. Should unsuitable material (e.g. fill, completely weathered rock, shear zones, etc.) be encountered, this will need to be removed.

8.2 Settlement

The settlement of shallow footings supported on the weathered greywacke rock under sustained loads (e.g. unfactored dead plus live loads) are expected to be minimal but should be confirmed once actual foundation types and loads are known.

9 Construction Considerations

9.1 Construction sequencing

The first step in construction is expected to be the demolition of the existing AGS building and clearance of the site. Once the AGS building has been removed the colluvial debris below the eastern and southern slopes can be removed, making way for the installation of the proposed slope treatment, ahead of construction of the proposed development.

Construction of the rock anchors and mesh will likely be undertaken using a combination of roped access and access from ground level using an elevated platform.

9.2 Excavations near the toe of the slope

Should excavations be required as part of the SMF development a buffer from the slope toe will be required to maintain slope stability, as recommended below:

For excavations less than 2m deep in rock, proposed excavations will need to maintain a buffer equal to a theoretical 45° plane from the base of the excavation to the toe of the rock (i.e. 1 horizontal to 1 vertical from the toe of the rock slope to the base of the excavation; see Figure 6).

For excavations greater than 2m deep, or if soils are encountered, specific geotechnical advice will be required prior to proceeding with the excavation.

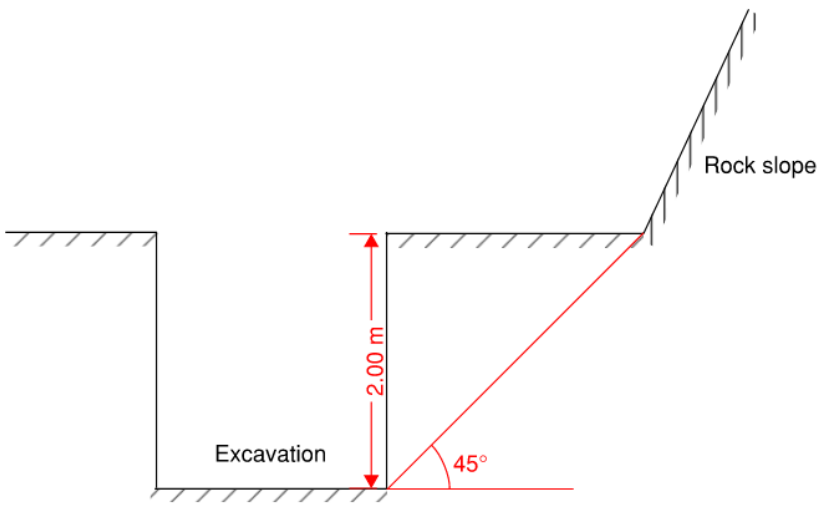


Figure 6. Sketch showing the minimum buffer (45° from the toe of the excavation) required from the toe of excavations up to 2m deep. Note that the sketch does not account for any shoring, benching or battering of the required for stability during construction.

9.3 Construction monitoring

Allowances should be made for a geotechnical engineer or engineering geologist to undertake regular monitoring during construction of:

- slope stabilisation measures, and
- excavations for foundations.

9.4 Space requirements

As part of the site layout design, a nominal horizontal distance of at least 3m from the toe of the existing cut slope should be maintained to allow for periodic maintenance of the slope treatment.

10 Applicability Statement

This report has been prepared by Connect Water on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which Beca has not given its prior written consent, is at that person's own risk.

Should you be in any doubt as to the applicability of this report and/or its recommendations for the proposed development as described herein, and/or encounter materials on site that differ from those described herein, it is essential that you discuss these issues with the authors before proceeding with any work based on this document.

11 References

AGS, 2007. *Practice Note Guidelines for Landslide Risk Management 2007*. Australian Geomechanics, 42(3).

Barnes P.M, Nodder S.D, Woelz S, Orpin A.R 2019: The structure and seismic potential of the Aotea and Evans Bay faults, Wellington, New Zealand, New Zealand Journal of Geology and Geophysics, vol. 62, no.1, 46-71p.

Beca, 2019. *AGS Building Slope Stabilisation: Geotechnical Input to Detailed Design of Rockfall Barrier*. Prepared for Wellington International Airport.

Beca Steven, 1990. Geotechnical Investigation Proposed Sites A and B Wellington Sewage Treatment Plant.

Begg, J.G., Mazengarb, C., 1996: Geology of the Wellington area, scale 1:50 000. Institute of Geological & Nuclear Sciences geological map 22. 1 sheet + 128 p. Lower Hutt, New Zealand: Institute of Geological & Nuclear Sciences Limited.

Begg, J.G., and Johnston, M.R., 2000: Geology of the Wellington area. Institute of Geological & Nuclear Sciences 1:250 000 geological map 10. 1 sheet + 64p. Lower Hutt, New Zealand: Institute of Geological & Nuclear Sciences Limited.

Connect Water, 2020a. *Sludge Minimisation Utilisation and Reclamation Facility: Geotechnical Desktop Study – Moa Point.* Prepared for Wellington Water.

Connect Water, 2020b. *Sludge Minimisation Utilisation and Reclamation Facility: Geotechnical Factual Report*. Prepared for Wellington Water.

Hoek, E. and Marinos, P., 2000. Predicting tunnel squeezing problems in weak heterogeneous rock masses. *Tunnels and tunnelling international*, *32*(11), pp.45-51.

Marinos, V.I.I.I., Marinos, P. and Hoek, E., 2005. The geological strength index: applications and limitations. *Bulletin of Engineering Geology and the Environment*, *64*(1), pp.55-65.

NZGS, 2016. *Earthquake geotechnical engineering practice. Module 1: Overview of the guidelines*. New Zealand Geotechnical Society (NZGS) and Ministry of Business Innovation & Employment (MBIE), Wellington. Rev. 0.

Waka Kotahi NZ Transport Agency, 2018. *Bridge Manual (SP/M022).*3rd Edition

Suneson, N.H., 1993: The geology of the Torlesse Complex along the Wellington area coast, North Island, New Zealand. New Zealand Journal of Geology and Geophysics, 36:3, 369-384

Standards New Zealand, 2016. *NZS 1170.5:2004, Structural design actions - Part 5: Earthquake actions - New Zealand*.

Appendix A: Site Plan

File: C:\Users\ck10\Desktop\Moa Point ArcGIS\Moa Point_Geotechnical_landscape.mxd Author: Date: 11/09/2020

Map Scale @ A3: 1:1,250

0 5 10 20 30 40 50

Meters

N

Revision	Author	Verified	Approved	Date
1	C. Kraus	J. Bradshaw	P. Horrey	11/09/2020

Title:

Site Investigation Plan

Client: **Wellington Water**

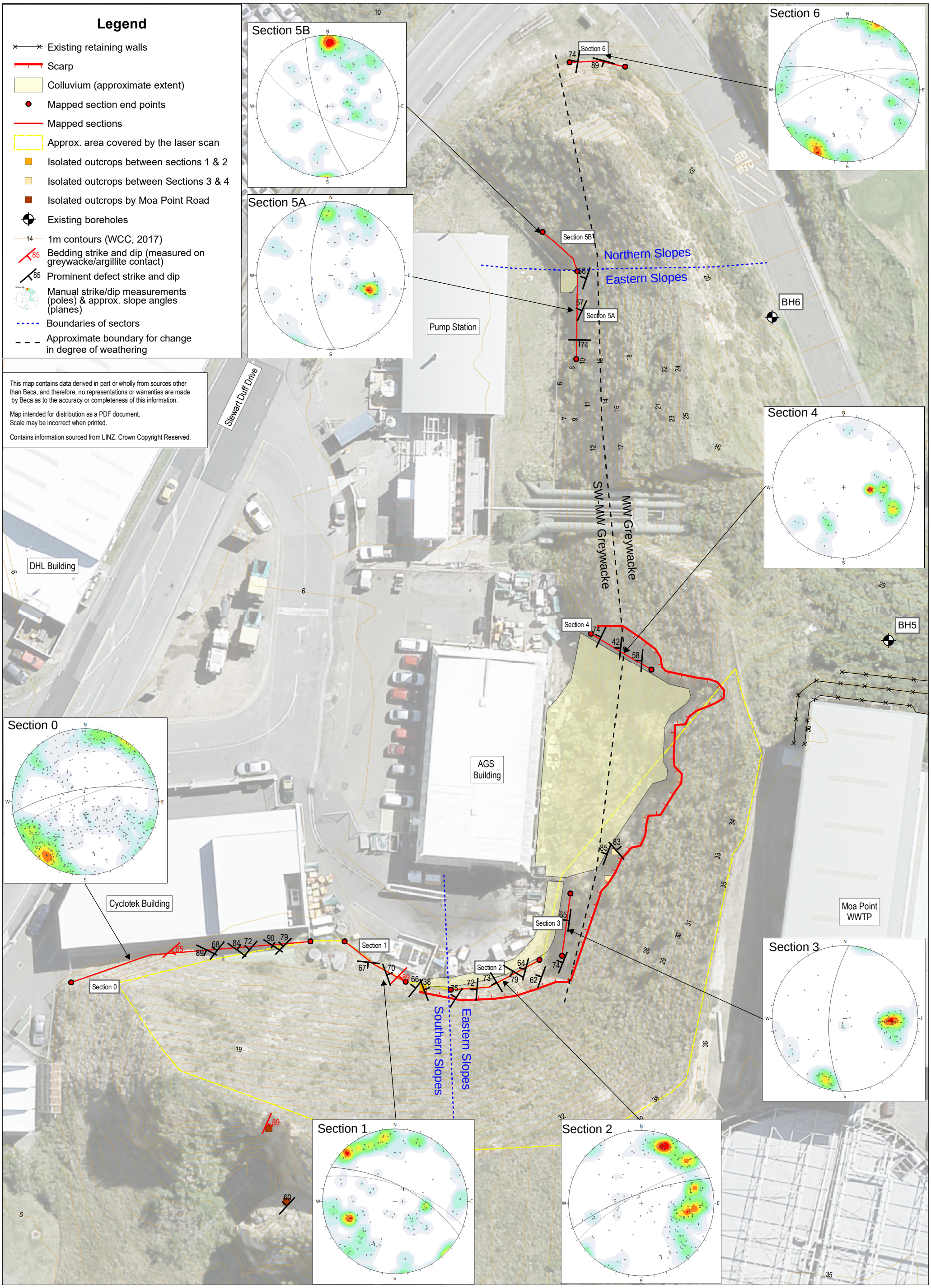
Project: **Wellington Sludge Minimisation Facility (SMF)**

CONNECT WATER

Discipline: **Geotechnical**

Drawing No:

Appendix B: Geological Map



File: \\Beca.net\projects\65\1651521\Work Packages\SMURF\6 - Technical Work and Design - Geotech\4. Technical Work & Design\6. Site plan and geological map\Moa Point_Geological Map.mxd Author: Date: 5/10/2020

Map Scale @ A3: 1:500

0 2.5 5 10 15 20 Meters

Revision	Author	Verified	Approved	Date
1	C. Kraus	J. Bradshaw	P. Horrey	07/10/2020

Title: **Geological Map**

Client: **Wellington Water**

Project: **Wellington Sludge Minimisation Facility (SMF)**

N

Discipline: **Geotechnical**

Drawing No: **PDF ONLY** NO DWG FILE

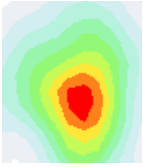
Appendix C: Kinematic Slope Stability Analyses

STEREONET AND KINEMATIC ANALYSIS LEGEND

Mean plane to defect set 1

Mean plane to defect set 2

Slope plane

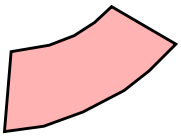


Density concentration of poles

Outline of poles in defect set 1

Outline of poles in defect set 2

Critical intersections



Critical zone

Secondary zone

Analytical boundaries

No.	Revision	By	Chk	Appd	Date

Client: WELLINGTON WATER

Project: WELLINGTON SLUDGE MINIMISATION FACILITY (SMF)

Design		
Drawn		
Dsg Verifier		
Dwg Check		

CONNECT WATER

Title: KINEMATIC ANALYSIS AND STEREONET KEY SHEET

Scale as drawn (A4)

Discipline

Drawing No. PDF ONLY NO DWG FILE

Rev. A

DO NOT SCALE

IF IN DOUBT ASK.

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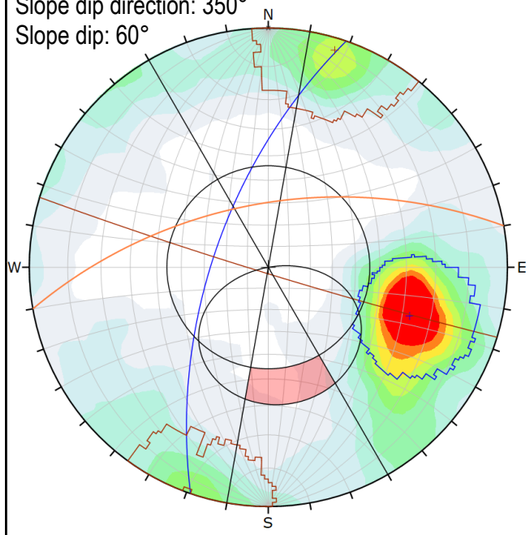
Slope dip: 60°



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Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding
Slope Dip	60
Slope Dip Direction	350
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	36	3235	1.11%

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1m		64	289	Set 1
2m		87	197	Set 2

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Hemisphere	Lower
Projection	Equal Angle

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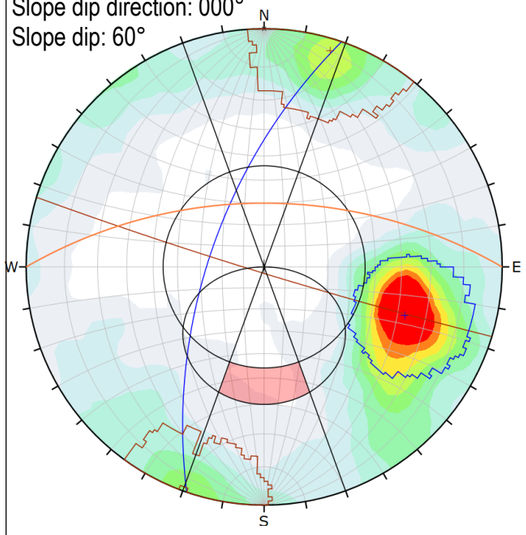
Slope dip: 60°



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	3.50 - 4.00
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Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding
Slope Dip	60
Slope Dip Direction	0
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	28	3235	0.87%

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Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

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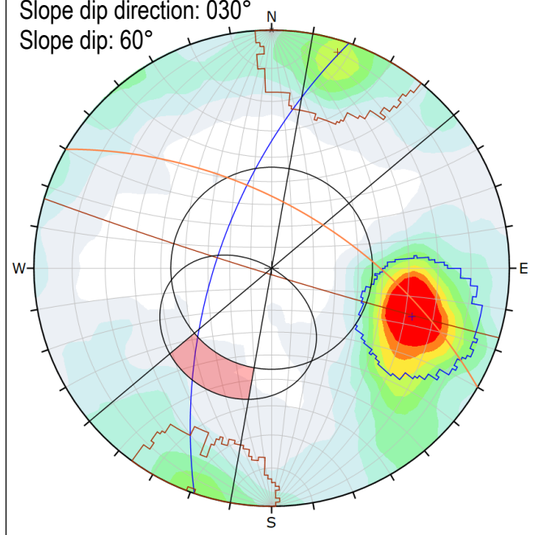
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 030°
Slope dip: 60°



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	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding
Slope Dip	60
Slope Dip Direction	30
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	37	3235	1.14%

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Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

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Hemisphere	Lower
Projection	Equal Angle

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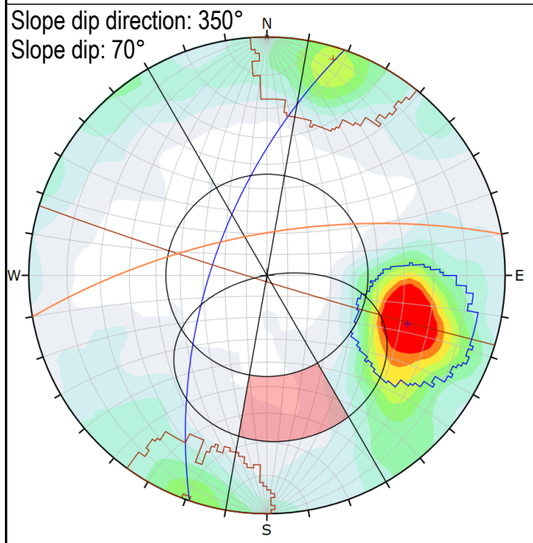
Slope dip: 70°



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Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding
Slope Dip	70
Slope Dip Direction	350
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	80	3235	2.47%

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1m		64	289	Set 1
2m		87	197	Set 2

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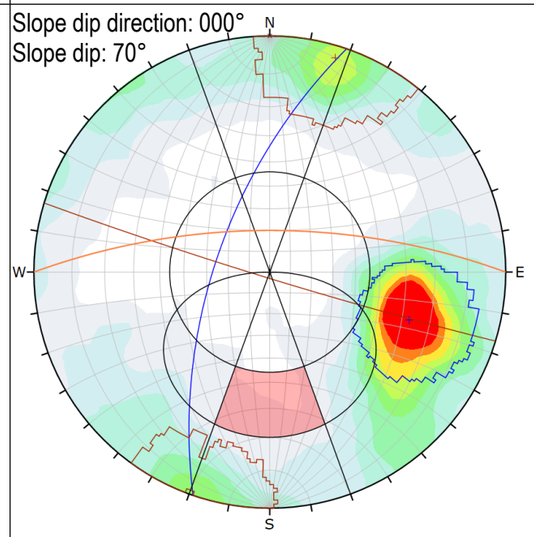
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 000°
Slope dip: 70°



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	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding
Slope Dip	70
Slope Dip Direction	0
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	62	3235	1.92%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

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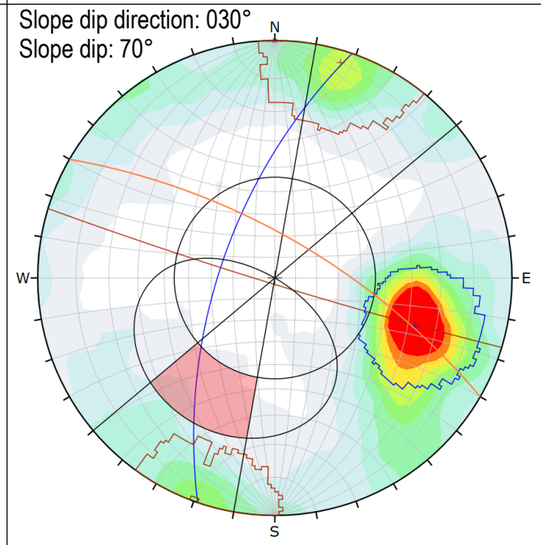
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 030°
Slope dip: 70°



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	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

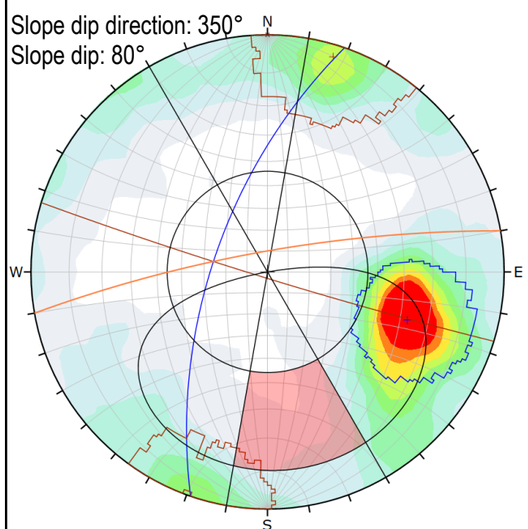
Kinematic Analysis	Planar Sliding
Slope Dip	70
Slope Dip Direction	30
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	100	3235	3.09%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 350°
Slope dip: 80°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

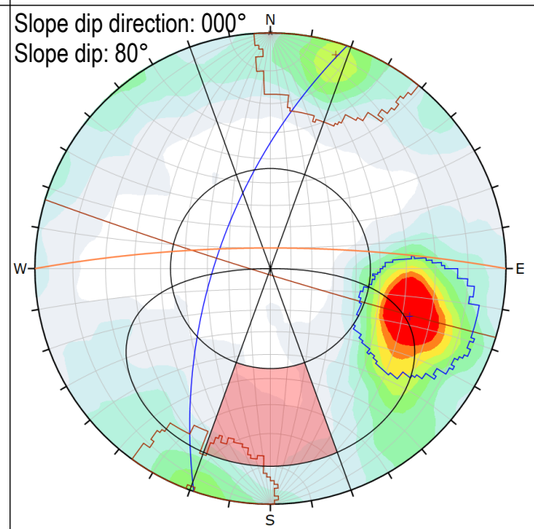
Kinematic Analysis	Planar Sliding
Slope Dip	80
Slope Dip Direction	350
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	137	3235	4.23%
Planar Sliding (Set 2: Set 2)	3	405	0.74%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 000°
Slope dip: 80°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

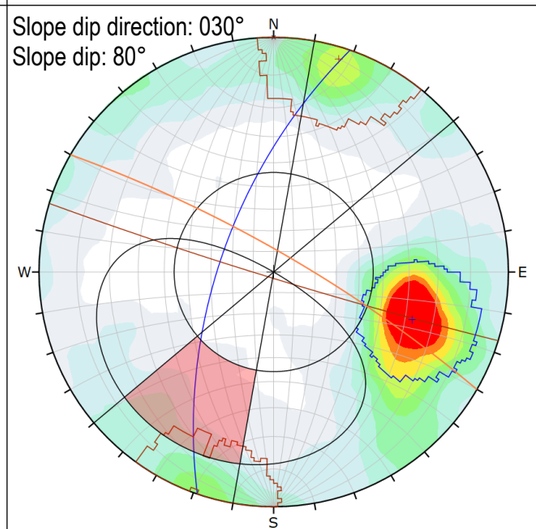
Kinematic Analysis	Planar Sliding
Slope Dip	80
Slope Dip Direction	0
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	123	3235	3.80%
Planar Sliding (Set 2: Set 2)	12	405	2.96%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 030°
Slope dip: 80°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding
Slope Dip	80
Slope Dip Direction	30
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	179	3235	5.53%
Planar Sliding (Set 2: Set 2)	22	405	5.43%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

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No.	Revision	By	Chk	Appd	Date

Drawing Originator: CONNECT WATER

Original Scale (A1)	Design	
	Drawn	
Reduced Scale (A3)	Dsg Verifier	
	Dwg Check	

* Refer to Revision 1 for Original Signature

Client: WELLINGTON WATER

Project: WELLINGTON SLUDGE MINIMISATION FACILITY (SMF)

Title: SECTOR 1: SOUTHERN SLOPES KINEMATIC ANALYSES FOR PLANAR SLIDING

Discipline: GEOTECHNICAL

Drawing No.: PDF ONLY NO DWG FILE

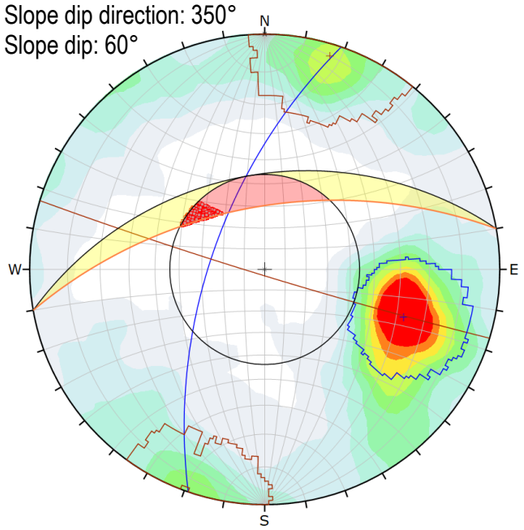
Rev.

BLUEBEAM

DO NOT SCALE

IF IN DOUBT ASK.

Slope dip direction: 350°
Slope dip: 60°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

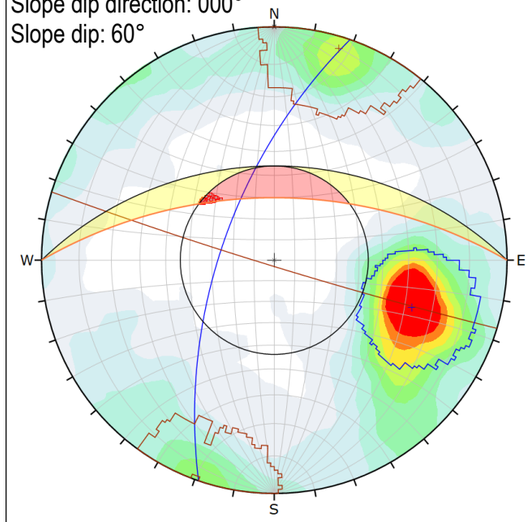
Kinematic Analysis	Wedge Sliding
Slope Dip	60
Slope Dip Direction	350
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	6085	328860	1.85%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 000°
Slope dip: 60°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

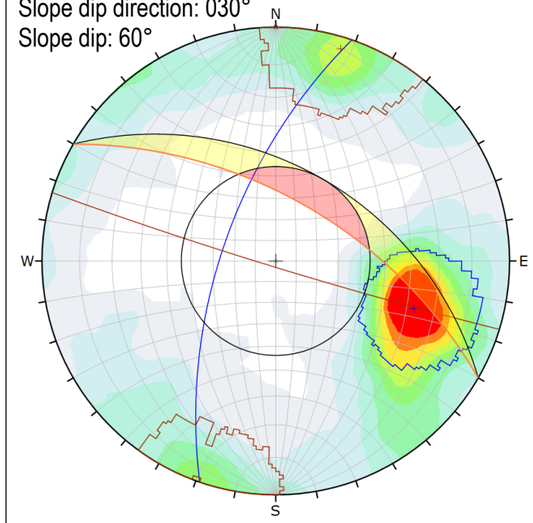
Kinematic Analysis	Wedge Sliding
Slope Dip	60
Slope Dip Direction	0
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	893	328860	0.27%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 030°
Slope dip: 60°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

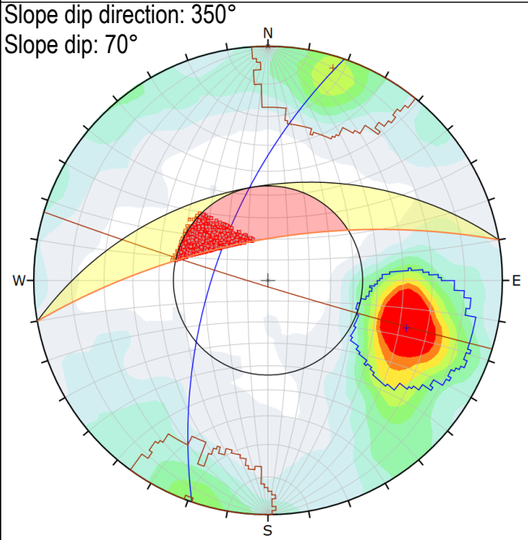
Kinematic Analysis	Wedge Sliding
Slope Dip	60
Slope Dip Direction	30
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	0	328860	0.00%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 350°
Slope dip: 70°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

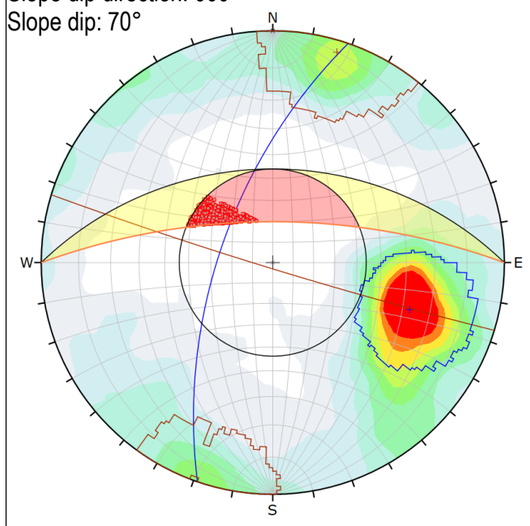
Kinematic Analysis	Wedge Sliding
Slope Dip	70
Slope Dip Direction	350
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	53326	328860	16.22%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 000°
Slope dip: 70°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

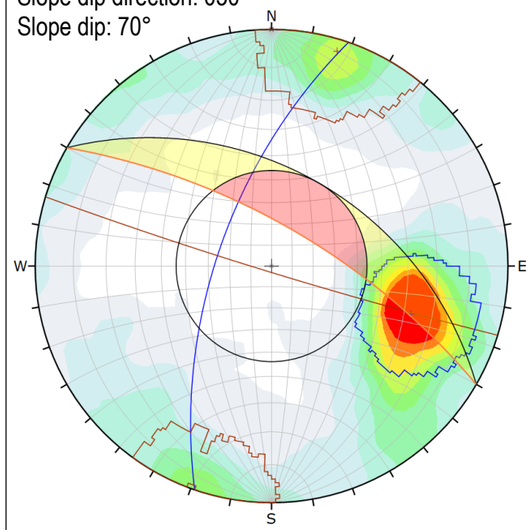
Kinematic Analysis	Wedge Sliding
Slope Dip	70
Slope Dip Direction	0
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	26164	328860	7.96%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 030°
Slope dip: 70°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

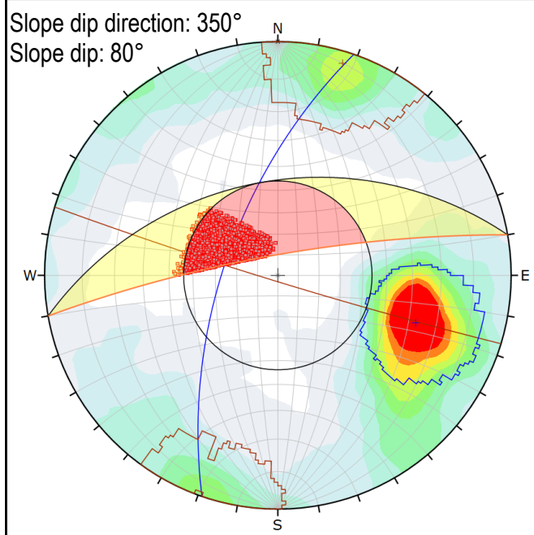
Kinematic Analysis	Wedge Sliding
Slope Dip	70
Slope Dip Direction	30
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	0	328860	0.00%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 350°
Slope dip: 80°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

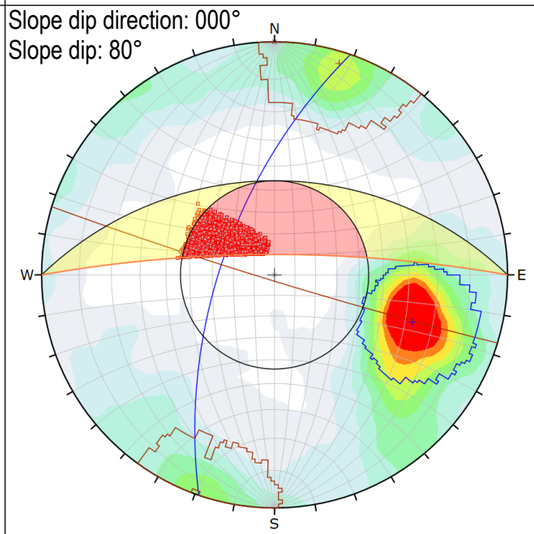
Kinematic Analysis	Wedge Sliding
Slope Dip	80
Slope Dip Direction	350
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	157136	328860	47.78%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 000°
Slope dip: 80°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

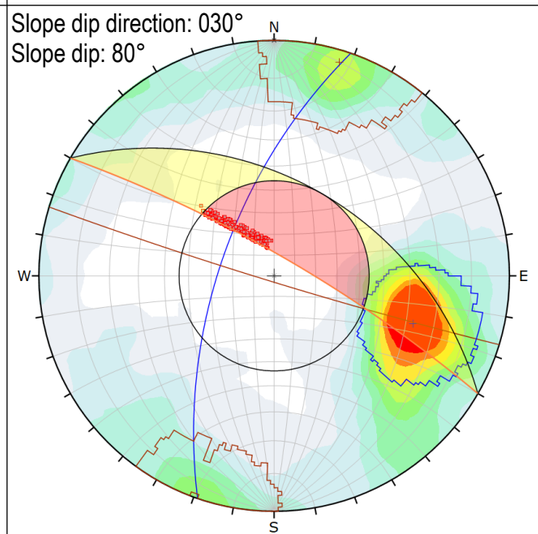
Kinematic Analysis	Wedge Sliding
Slope Dip	80
Slope Dip Direction	0
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	105501	328860	32.08%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 030°
Slope dip: 80°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Wedge Sliding
Slope Dip	80
Slope Dip Direction	30
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	8198	328860	2.49%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

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No.	Revision	By	Chk	Appd	Date

Drawing Originator: CONNECT WATER

Original Scale (A1)	Design			
	Drawn			
Reduced Scale (A3)	Dsg Verifier			
	Dwg Check			

* Refer to Revision 1 for Original Signature

Client: WELLINGTON WATER

Project: WELLINGTON SLUDGE MINIMISATION FACILITY (SMF)

Title: SECTOR 1: SOUTHERN SLOPES KINEMATIC ANALYSES FOR WEDGE SLIDING

Discipline: GEOTECHNICAL

Drawing No.: PDF ONLY NO DWG FILE

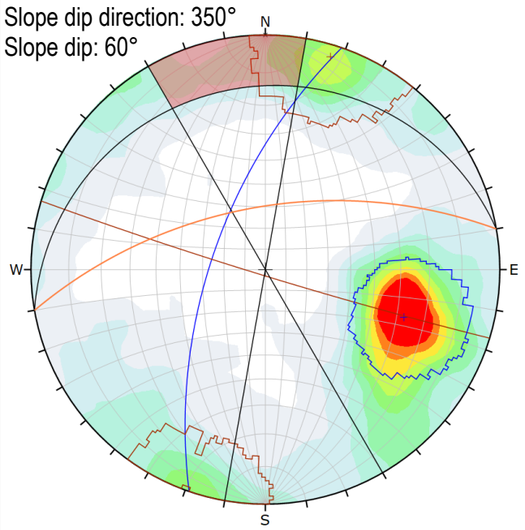
Rev.

BLUEBEAM

DO NOT SCALE

IF IN DOUBT ASK.

Slope dip direction: 350°
Slope dip: 60°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

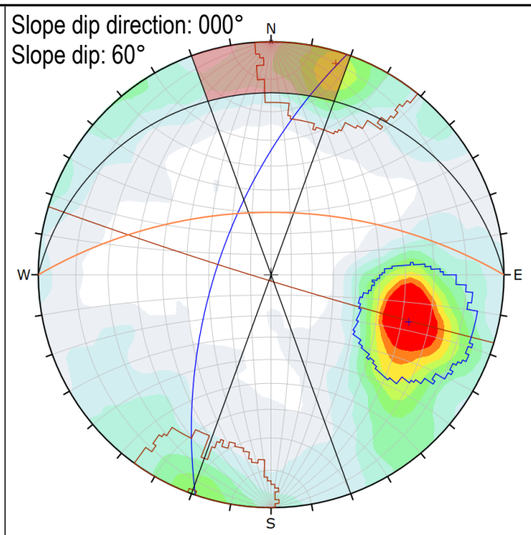
Kinematic Analysis	Flexural Toppling
Slope Dip	60
Slope Dip Direction	350
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Flexural Toppling (All)	167	3235	5.16%
Flexural Toppling (Set 2: Set 2)	67	405	16.54%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 000°
Slope dip: 60°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

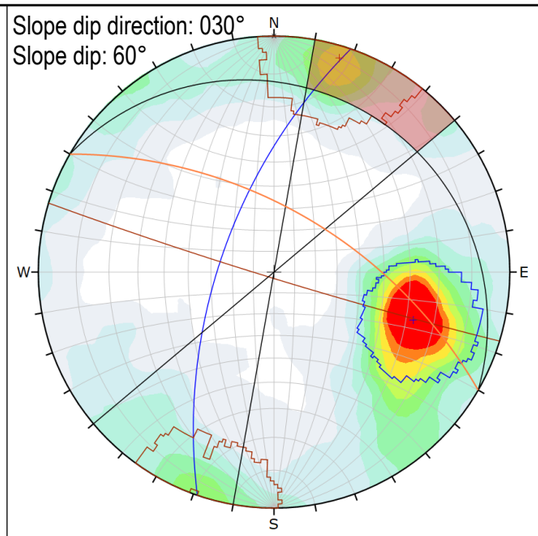
Kinematic Analysis	Flexural Toppling
Slope Dip	60
Slope Dip Direction	0
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Flexural Toppling (All)	219	3235	6.77%
Flexural Toppling (Set 2: Set 2)	152	405	37.53%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 030°
Slope dip: 60°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

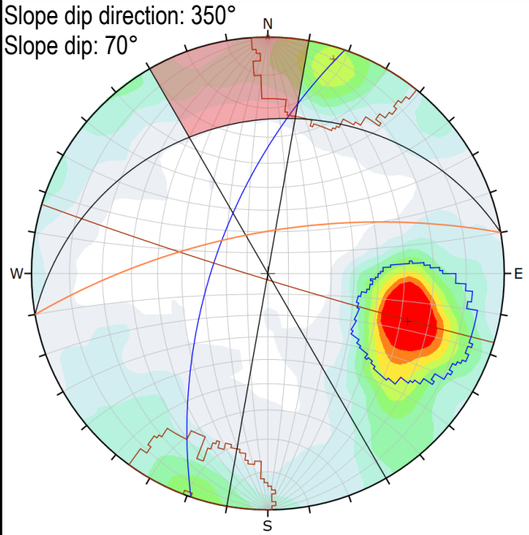
Kinematic Analysis	Flexural Toppling
Slope Dip	60
Slope Dip Direction	30
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Flexural Toppling (All)	206	3235	6.37%
Flexural Toppling (Set 2: Set 2)	164	405	40.49%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 350°
Slope dip: 70°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

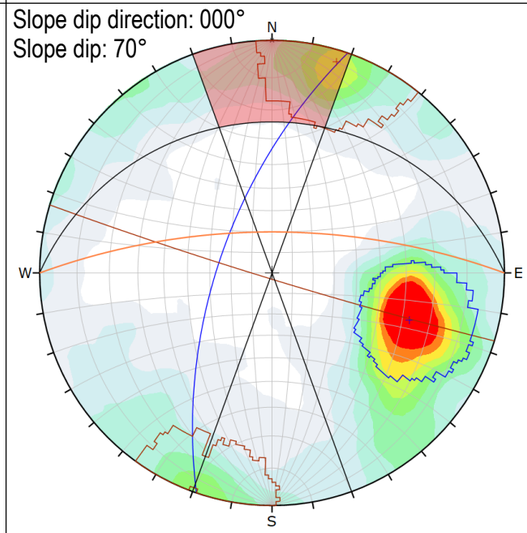
Kinematic Analysis	Flexural Toppling
Slope Dip	70
Slope Dip Direction	350
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Flexural Toppling (All)	219	3235	6.77%
Flexural Toppling (Set 2: Set 2)	77	405	19.01%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 000°
Slope dip: 70°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

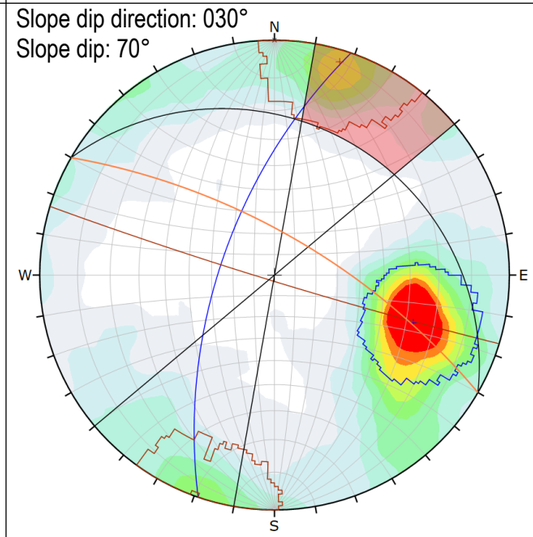
Kinematic Analysis	Flexural Toppling
Slope Dip	70
Slope Dip Direction	0
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Flexural Toppling (All)	277	3235	8.56%
Flexural Toppling (Set 2: Set 2)	180	405	44.44%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 030°
Slope dip: 70°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

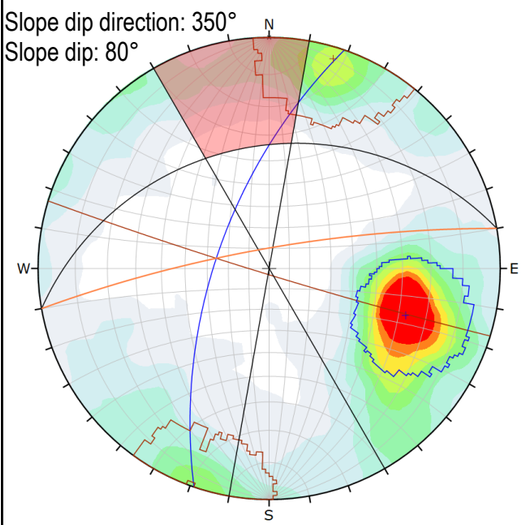
Kinematic Analysis	Flexural Toppling
Slope Dip	70
Slope Dip Direction	30
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Flexural Toppling (All)	269	3235	8.32%
Flexural Toppling (Set 2: Set 2)	199	405	49.14%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 350°
Slope dip: 80°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

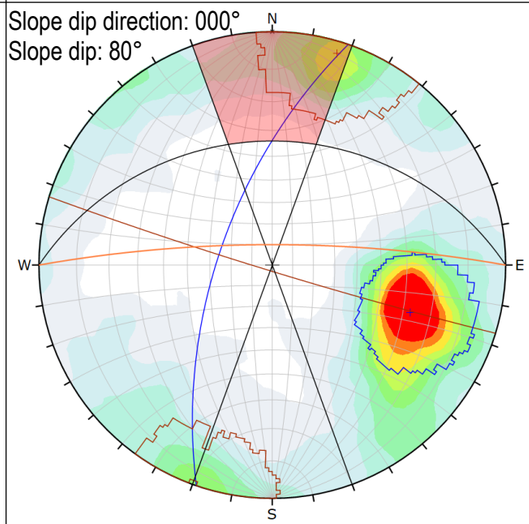
Kinematic Analysis	Flexural Toppling
Slope Dip	80
Slope Dip Direction	350
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Flexural Toppling (All)	237	3235	7.33%
Flexural Toppling (Set 2: Set 2)	77	405	19.01%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 000°
Slope dip: 80°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

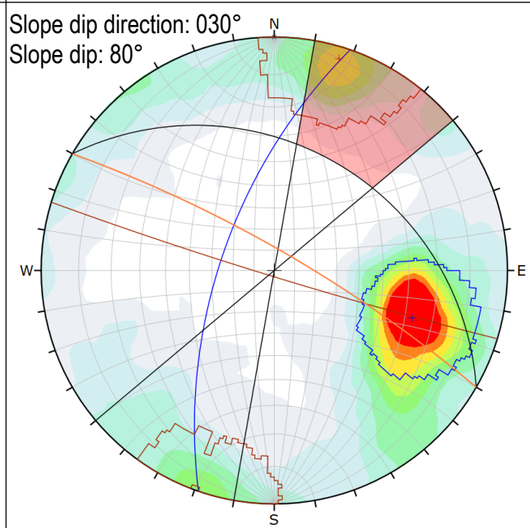
Kinematic Analysis	Flexural Toppling
Slope Dip	80
Slope Dip Direction	0
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Flexural Toppling (All)	302	3235	9.34%
Flexural Toppling (Set 2: Set 2)	180	405	44.44%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 030°
Slope dip: 80°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling
Slope Dip	80
Slope Dip Direction	30
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Flexural Toppling (All)	298	3235	9.21%
Flexural Toppling (Set 2: Set 2)	199	405	49.14%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

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No.	Revision	By	Chk	Appd	Date

Drawing Originator: CONNECT WATER

Original Scale (A1)	Design		
	Drawn		
Reduced Scale (A3)	Dsg Verifier		
	Dwg Check		
	* Refer to Revision 1 for Original Signature		

Client: WELLINGTON WATER

Project: WELLINGTON SLUDGE MINIMISATION FACILITY (SMF)

Title: SECTOR 1: SOUTHERN SLOPES KINEMATIC ANALYSES FOR FLEXURAL TOPPLING

Discipline: GEOTECHNICAL

Drawing No.: PDF ONLY NO DWG FILE

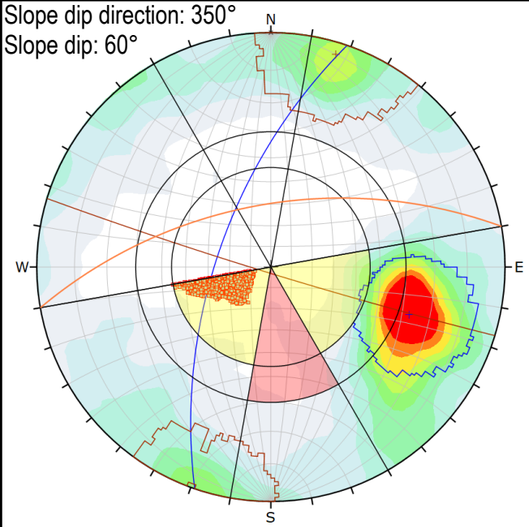
Rev.

BLIEBEAM

DO NOT SCALE

IF IN DOUBT ASK.

Slope dip direction: 350°
Slope dip: 60°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

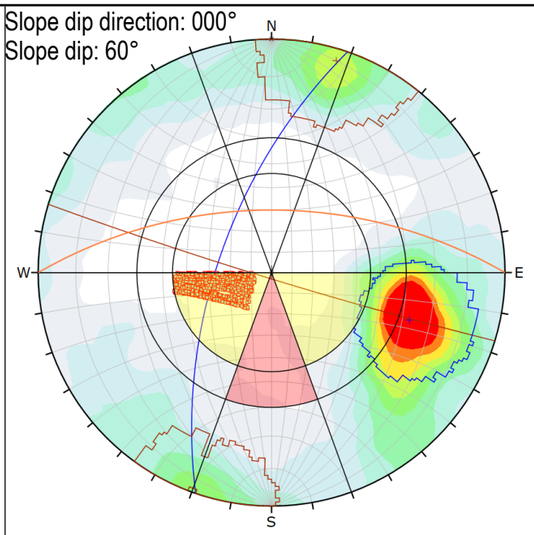
Kinematic Analysis	Direct Toppling
Slope Dip	60
Slope Dip Direction	350
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	58065	328860	17.66%
Base Plane (All)	308	3235	9.52%
Base Plane (Set 1: Set 1)	6	812	0.74%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 000°
Slope dip: 60°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

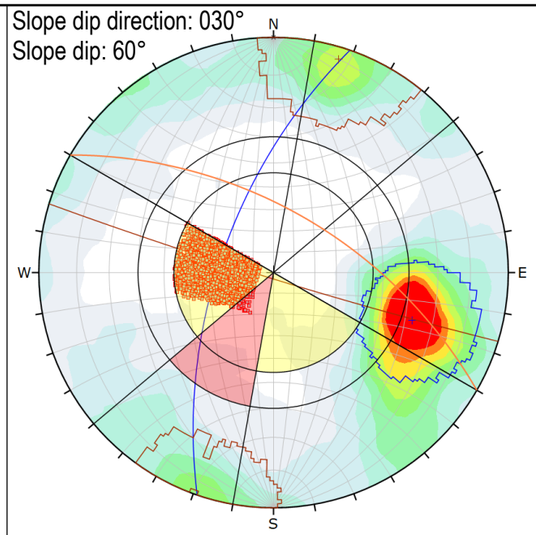
Kinematic Analysis	Direct Toppling
Slope Dip	60
Slope Dip Direction	0
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	111488	328860	33.90%
Base Plane (All)	285	3235	8.81%
Base Plane (Set 1: Set 1)	6	812	0.74%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 030°
Slope dip: 60°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

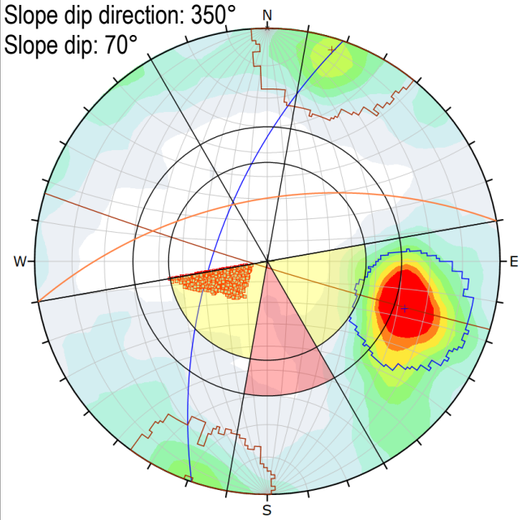
Kinematic Analysis	Direct Toppling
Slope Dip	60
Slope Dip Direction	30
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	2471	328860	0.75%
Oblique Toppling (Intersection)	257938	328860	78.43%
Base Plane (All)	244	3235	7.54%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 350°
Slope dip: 70°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

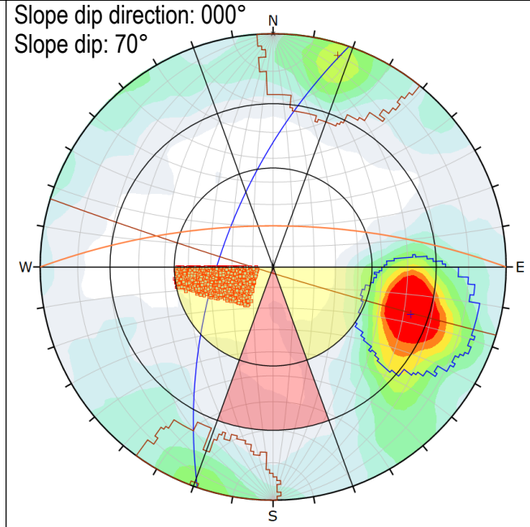
Kinematic Analysis	Direct Toppling
Slope Dip	60
Slope Dip Direction	350
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	58065	328860	17.66%
Base Plane (All)	308	3235	9.52%
Base Plane (Set 1: Set 1)	6	812	0.74%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 000°
Slope dip: 70°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

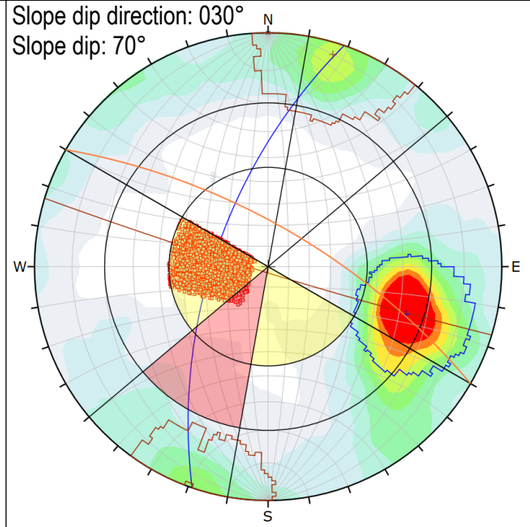
Kinematic Analysis	Direct Toppling
Slope Dip	70
Slope Dip Direction	0
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	111488	328860	33.90%
Base Plane (All)	316	3235	9.77%
Base Plane (Set 1: Set 1)	6	812	0.74%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 030°
Slope dip: 70°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

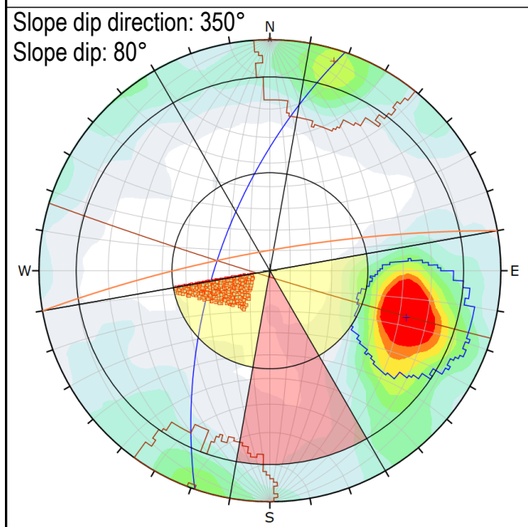
Kinematic Analysis	Direct Toppling
Slope Dip	70
Slope Dip Direction	30
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	2471	328860	0.75%
Oblique Toppling (Intersection)	257938	328860	78.43%
Base Plane (All)	304	3235	9.40%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 350°
Slope dip: 80°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

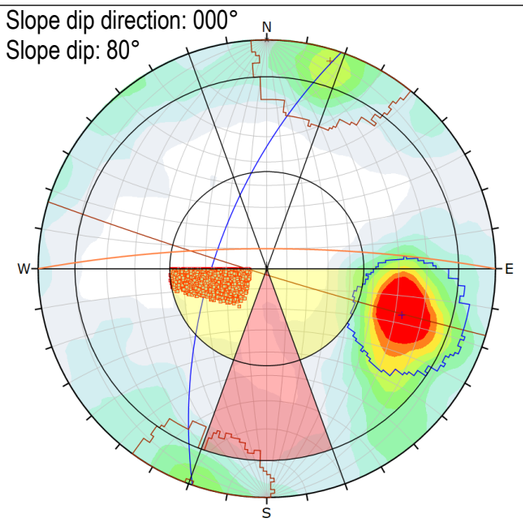
Kinematic Analysis	Direct Toppling
Slope Dip	80
Slope Dip Direction	350
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	58065	328860	17.66%
Base Plane (All)	407	3235	12.58%
Base Plane (Set 1: Set 1)	6	812	0.74%
Base Plane (Set 2: Set 2)	4	405	0.99%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 000°
Slope dip: 80°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

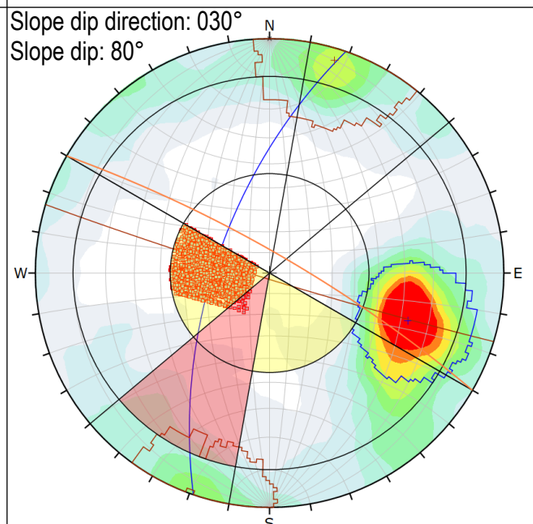
Kinematic Analysis	Direct Toppling
Slope Dip	80
Slope Dip Direction	0
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	111488	328860	33.90%
Base Plane (All)	376	3235	11.62%
Base Plane (Set 1: Set 1)	6	812	0.74%
Base Plane (Set 2: Set 2)	16	405	3.95%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 030°
Slope dip: 80°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Direct Toppling
Slope Dip	80
Slope Dip Direction	30
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	2471	328860	0.75%
Oblique Toppling (Intersection)	257938	328860	78.43%
Base Plane (All)	393	3235	12.15%
Base Plane (Set 2: Set 2)	35	405	8.64%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

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No.	Revision	By	Chk	Appd	Date

Drawing Originator: CONNECT WATER

Original Scale (A1)	Design		
	Drawn		
Reduced Scale (A3)	Dsg Verifier		
	Dwg Check		

* Refer to Revision 1 for Original Signature

Client: WELLINGTON WATER

Project: WELLINGTON SLUDGE MINIMISATION FACILITY (SMF)

Title: SECTOR 1: SOUTHERN SLOPES KINEMATIC ANALYSES FOR DIRECT TOPPLING

Discipline: GEOTECHNICAL

Drawing No.: PDF ONLY NO DWG FILE

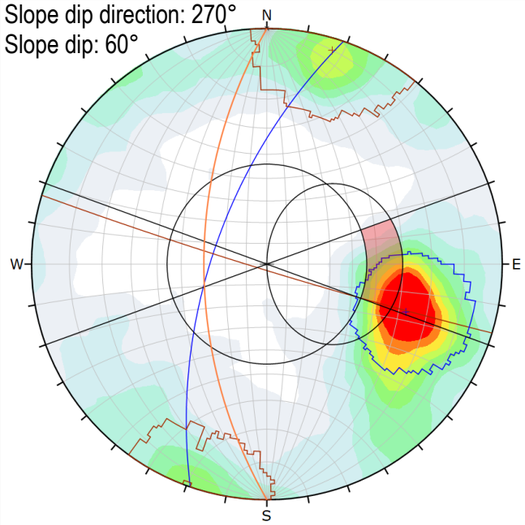
Rev.

BLUEBEAM

DO NOT SCALE

IF IN DOUBT ASK.

Slope dip direction: 270°
Slope dip: 60°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

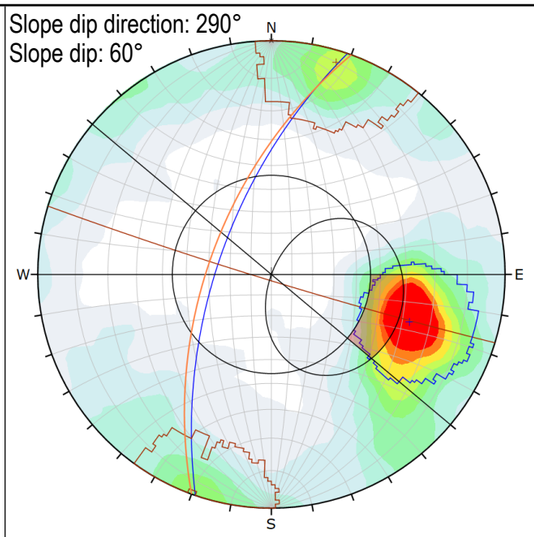
Kinematic Analysis	Planar Sliding
Slope Dip	60
Slope Dip Direction	270
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	176	3235	5.44%
Planar Sliding (Set 1: Set 1)	132	812	16.26%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 290°
Slope dip: 60°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

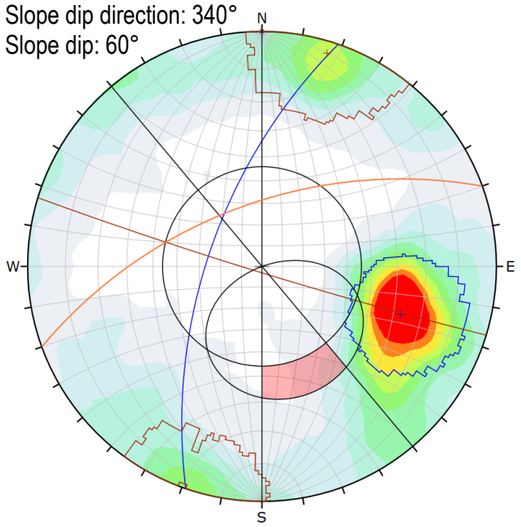
Kinematic Analysis	Planar Sliding
Slope Dip	60
Slope Dip Direction	290
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	235	3235	7.26%
Planar Sliding (Set 1: Set 1)	218	812	26.85%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 340°
Slope dip: 60°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

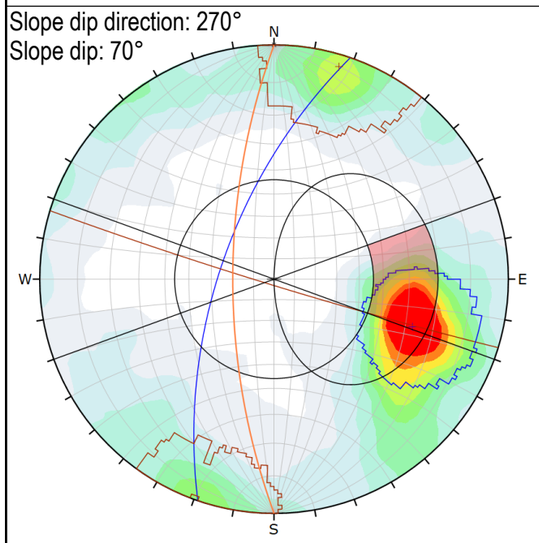
Kinematic Analysis	Planar Sliding
Slope Dip	60
Slope Dip Direction	340
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	48	3235	1.48%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 270°
Slope dip: 70°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

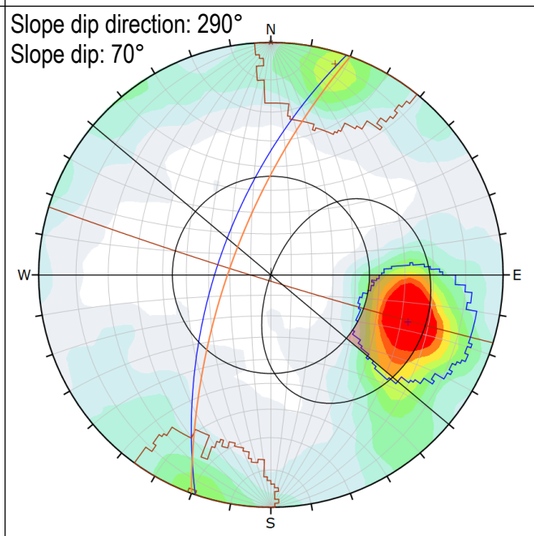
Kinematic Analysis	Planar Sliding
Slope Dip	70
Slope Dip Direction	270
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	413	3235	12.77%
Planar Sliding (Set 1: Set 1)	333	812	41.01%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 290°
Slope dip: 70°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

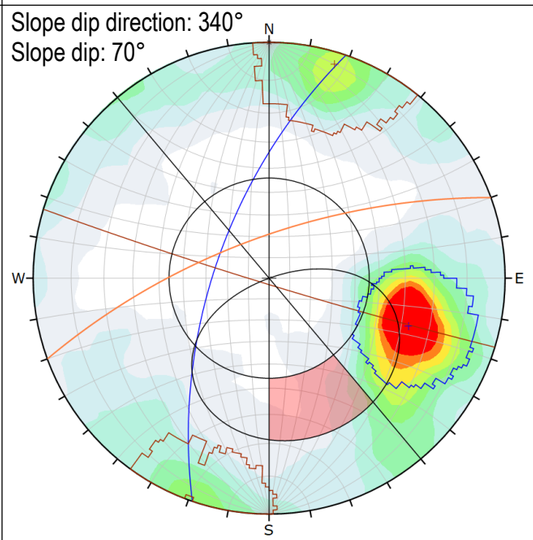
Kinematic Analysis	Planar Sliding
Slope Dip	70
Slope Dip Direction	290
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	552	3235	17.06%
Planar Sliding (Set 1: Set 1)	535	812	65.89%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 340°
Slope dip: 70°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

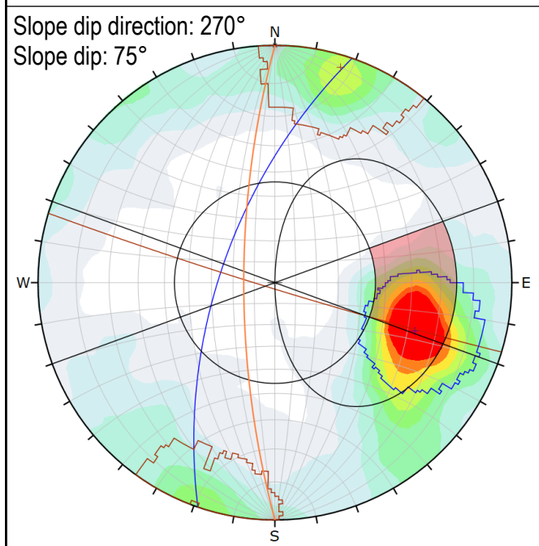
Kinematic Analysis	Planar Sliding
Slope Dip	70
Slope Dip Direction	340
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	99	3235	3.06%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 270°
Slope dip: 75°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

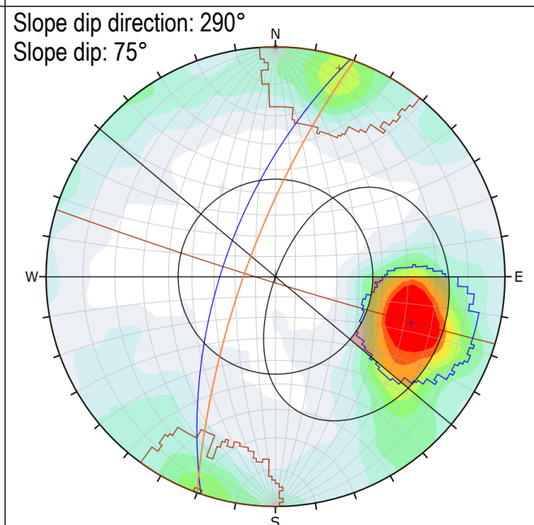
Kinematic Analysis	Planar Sliding
Slope Dip	75
Slope Dip Direction	270
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	492	3235	15.21%
Planar Sliding (Set 1: Set 1)	387	812	47.66%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 290°
Slope dip: 75°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

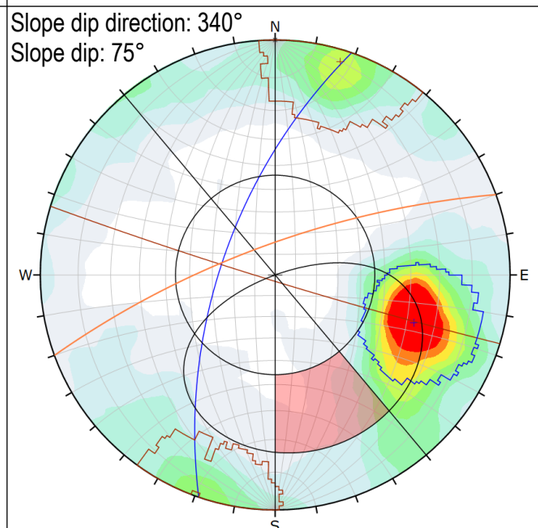
Kinematic Analysis	Planar Sliding
Slope Dip	75
Slope Dip Direction	290
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	680	3235	21.02%
Planar Sliding (Set 1: Set 1)	658	812	81.03%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 340°
Slope dip: 75°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding
Slope Dip	75
Slope Dip Direction	340
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	134	3235	4.14%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

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No.	Revision	By	Chk	Appd	Date

Drawing Originator: CONNECT WATER

Original Scale (A1)	Design		
	Drawn		
Reduced Scale (A3)	Dsg Verifier		
	Dwg Check		

* Refer to Revision 1 for Original Signature

Client: WELLINGTON WATER

Project: WELLINGTON SLUDGE MINIMISATION FACILITY (SMF)

Title: SECTOR 2: EASTERN AND SOUTHEASTERN SLOPES. KINEMATIC ANALYSES FOR PLANAR SLIDING

Discipline: GEOTECHNICAL

Drawing No.: PDF ONLY NO DWG FILE

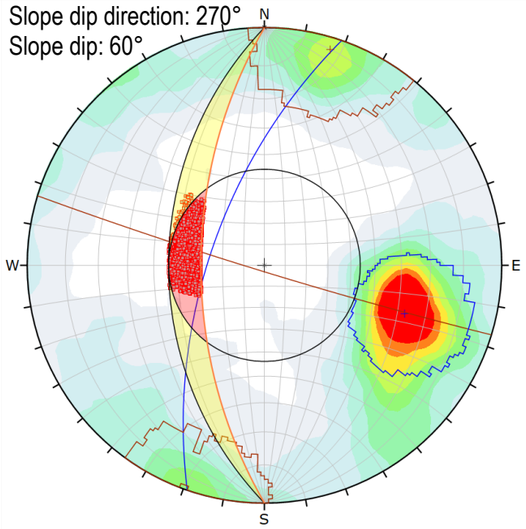
Rev.

BLUEBEAM

DO NOT SCALE

IF IN DOUBT ASK.

Slope dip direction: 270°
Slope dip: 60°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

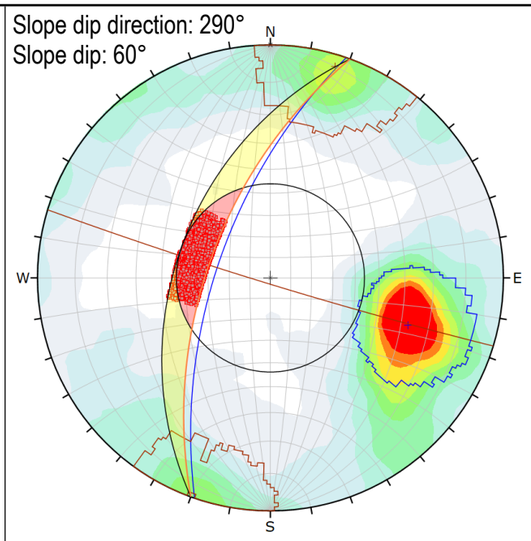
Kinematic Analysis	Wedge Sliding
Slope Dip	60
Slope Dip Direction	270
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	105421	328860	32.06%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 290°
Slope dip: 60°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

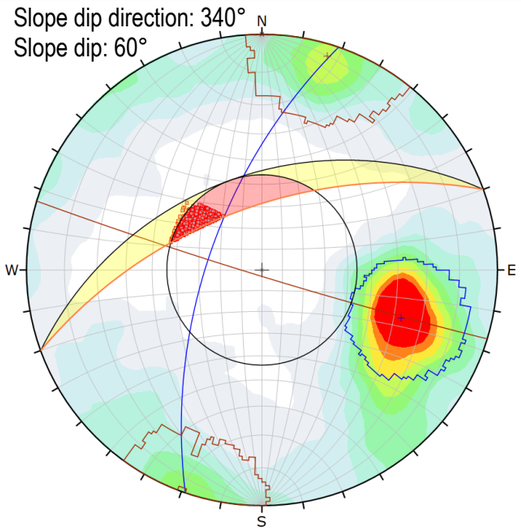
Kinematic Analysis	Wedge Sliding
Slope Dip	60
Slope Dip Direction	290
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	108756	328860	33.07%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 340°
Slope dip: 60°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

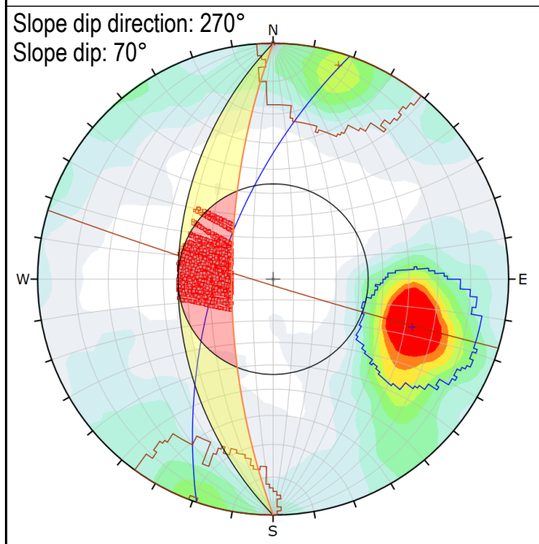
Kinematic Analysis	Wedge Sliding
Slope Dip	60
Slope Dip Direction	340
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	17042	328860	5.18%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 270°
Slope dip: 70°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

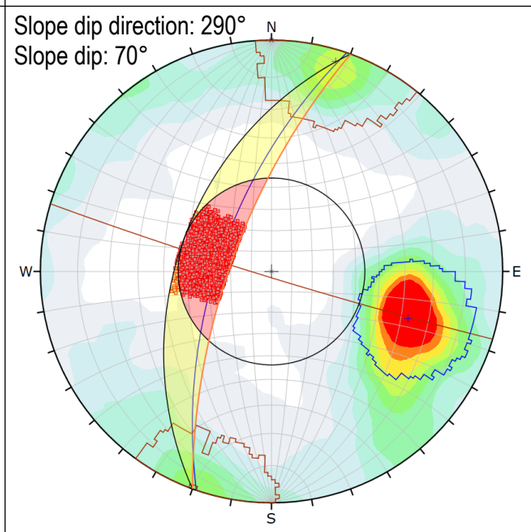
Kinematic Analysis	Wedge Sliding
Slope Dip	70
Slope Dip Direction	270
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	236478	328860	71.91%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 290°
Slope dip: 70°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

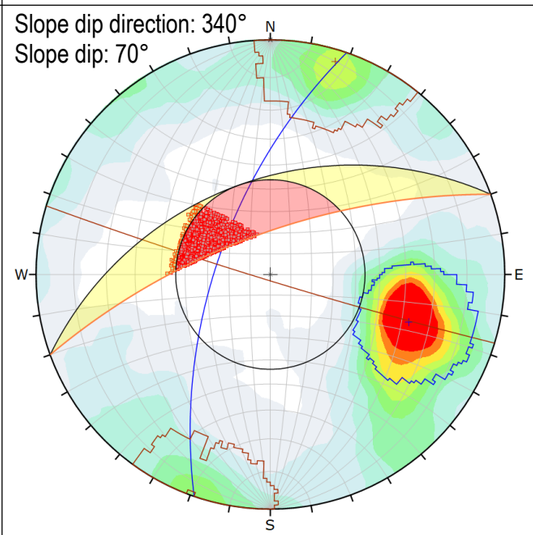
Kinematic Analysis	Wedge Sliding
Slope Dip	70
Slope Dip Direction	290
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	237941	328860	72.35%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 340°
Slope dip: 70°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

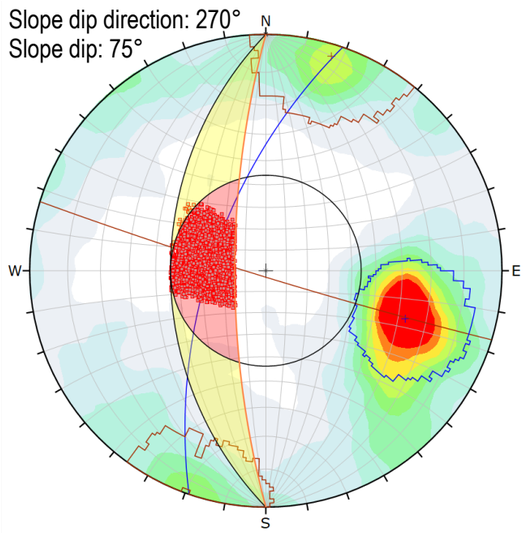
Kinematic Analysis	Wedge Sliding
Slope Dip	70
Slope Dip Direction	340
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	89317	328860	27.16%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 270°
Slope dip: 75°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

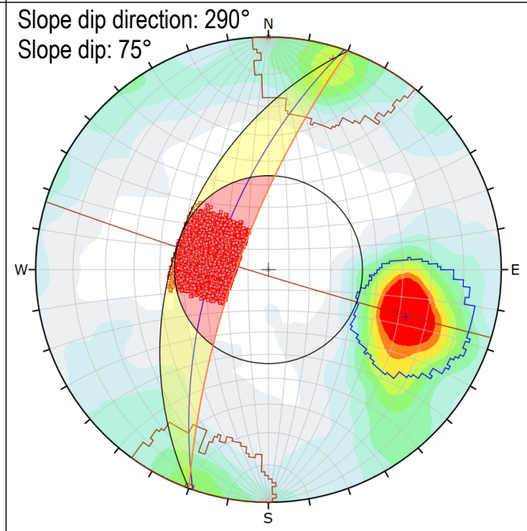
Kinematic Analysis	Wedge Sliding
Slope Dip	75
Slope Dip Direction	270
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	280737	328860	85.37%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 290°
Slope dip: 75°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

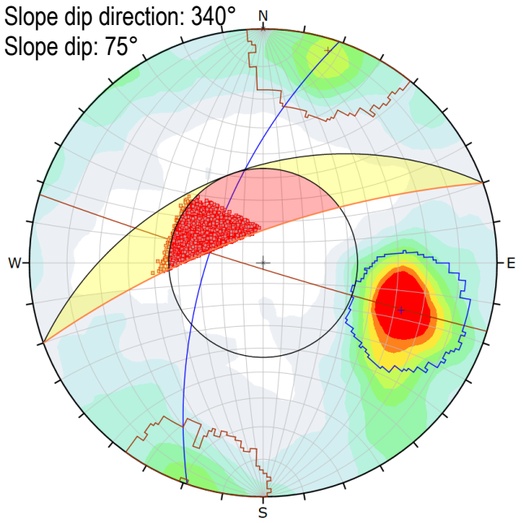
Kinematic Analysis	Wedge Sliding
Slope Dip	75
Slope Dip Direction	290
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	282687	328860	85.96%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 340°
Slope dip: 75°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Wedge Sliding
Slope Dip	75
Slope Dip Direction	340
Friction Angle	46°

	Critical	Total	%
Wedge Sliding	148336	328860	45.11%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

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No.	Revision	By	Chk	Appd	Date

Drawing Originator: CONNECT WATER

Original Scale (A1)	Design		
	Drawn		
Reduced Scale (A3)	Dsg Verifier		
	Dwg Check		

* Refer to Revision 1 for Original Signature

Client: WELLINGTON WATER

Project: WELLINGTON SLUDGE MINIMISATION FACILITY (SMF)

Title: SECTOR 2: EASTERN AND SOUTHEASTERN SLOPES. KINEMATIC ANALYSES FOR WEDGE SLIDING

Discipline: GEOTECHNICAL

Drawing No.: PDF ONLY NO DWG FILE

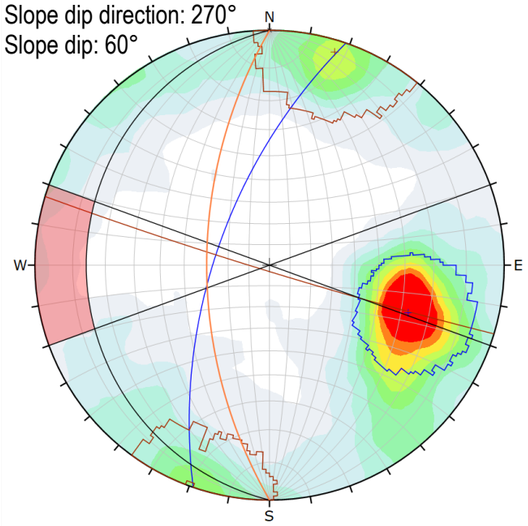
Rev.

BLUEBEAM

DO NOT SCALE

IF IN DOUBT ASK.

Slope dip direction: 270°
Slope dip: 60°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

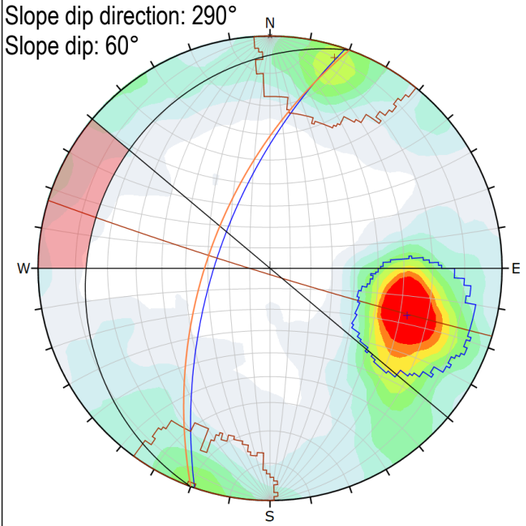
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling		
Slope Dip	60		
Slope Dip Direction	270		
Friction Angle	46°		
Lateral Limits	20°		
	Critical	Total	%
Flexural Toppling (All)	65	3235	2.01%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 290°
Slope dip: 60°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

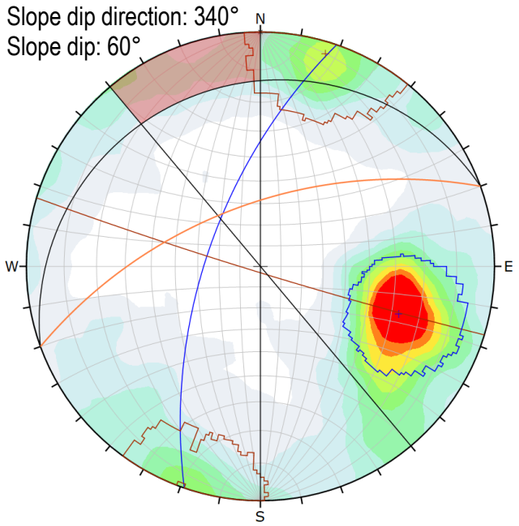
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling		
Slope Dip	60		
Slope Dip Direction	290		
Friction Angle	46°		
Lateral Limits	20°		
	Critical	Total	%
Flexural Toppling (All)	88	3235	2.72%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 340°
Slope dip: 60°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

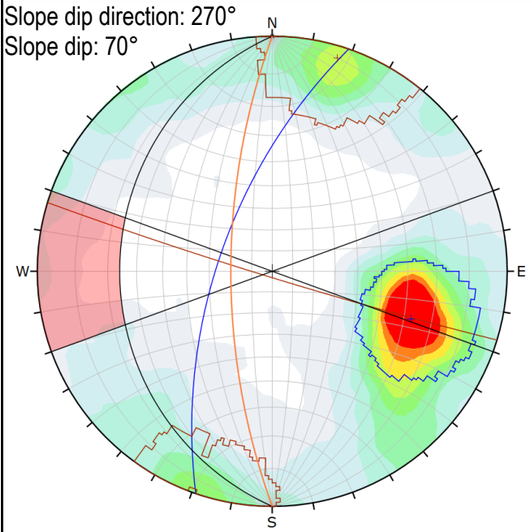
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling		
Slope Dip	60		
Slope Dip Direction	340		
Friction Angle	46°		
Lateral Limits	20°		
	Critical	Total	%
Flexural Toppling (All)	157	3235	4.85%
Flexural Toppling (Set 2: Set 2)	21	405	5.19%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 270°
Slope dip: 70°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

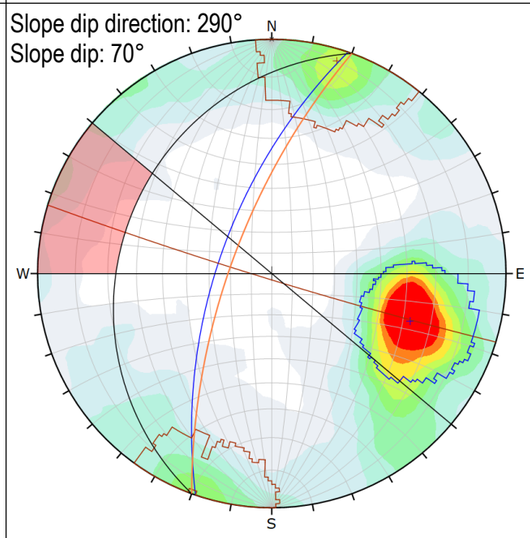
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling		
Slope Dip	70		
Slope Dip Direction	270		
Friction Angle	46°		
Lateral Limits	20°		
	Critical	Total	%
Flexural Toppling (All)	97	3235	3.00%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 290°
Slope dip: 70°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

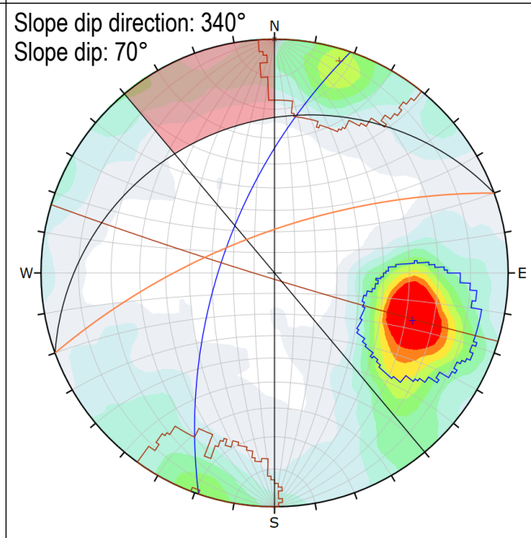
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling		
Slope Dip	70		
Slope Dip Direction	290		
Friction Angle	46°		
Lateral Limits	20°		
	Critical	Total	%
Flexural Toppling (All)	122	3235	3.77%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 340°
Slope dip: 70°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

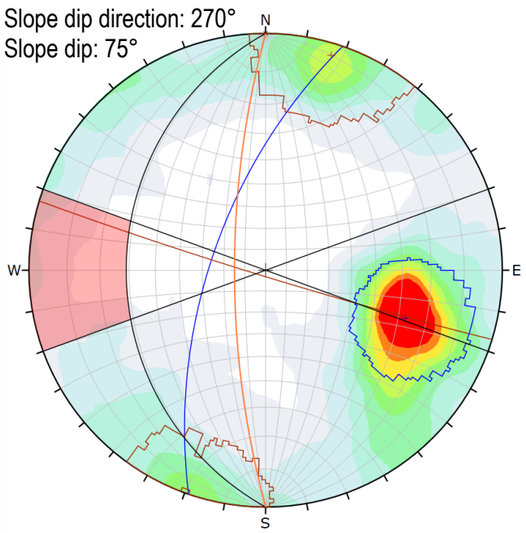
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling		
Slope Dip	70		
Slope Dip Direction	340		
Friction Angle	46°		
Lateral Limits	20°		
	Critical	Total	%
Flexural Toppling (All)	202	3235	6.24%
Flexural Toppling (Set 2: Set 2)	21	405	5.19%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 270°
Slope dip: 75°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

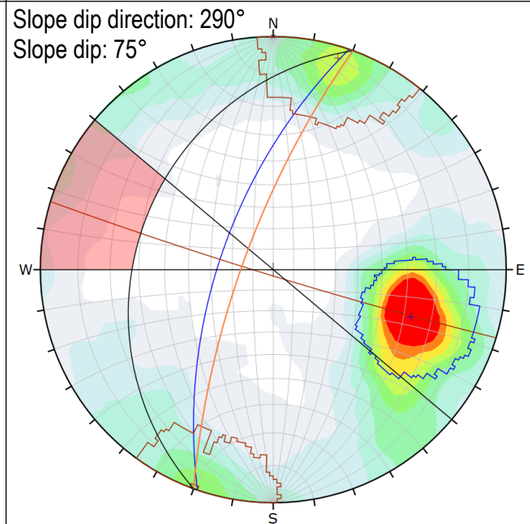
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling		
Slope Dip	75		
Slope Dip Direction	270		
Friction Angle	46°		
Lateral Limits	20°		
	Critical	Total	%
Flexural Toppling (All)	105	3235	3.25%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 290°
Slope dip: 75°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

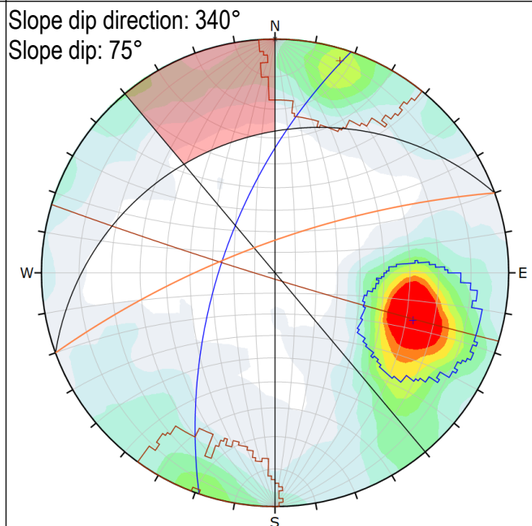
Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling		
Slope Dip	75		
Slope Dip Direction	290		
Friction Angle	46°		
Lateral Limits	20°		
	Critical	Total	%
Flexural Toppling (All)	131	3235	4.05%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 340°
Slope dip: 75°



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling		
Slope Dip	75		
Slope Dip Direction	340		
Friction Angle	46°		
Lateral Limits	20°		
	Critical	Total	%
Flexural Toppling (All)	212	3235	6.55%
Flexural Toppling (Set 2: Set 2)	21	405	5.19%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Hemisphere	Lower
Projection	Equal Angle

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No.	Revision	By	Chk	Appd	Date

Drawing Originator: CONNECT WATER

Original Scale (A1)	Design		
	Drawn		
Reduced Scale (A3)	Dsg Verifier		
	Dwg Check		

* Refer to Revision 1 for Original Signature

Client: WELLINGTON WATER

Project: WELLINGTON SLUDGE MINIMISATION FACILITY (SMF)

Title: SECTOR 2: EASTERN AND SOUTHEASTERN SLOPES. KINEMATIC ANALYSES FOR FLEXURAL TOPPLING

Discipline: GEOTECHNICAL

Drawing No.: PDF ONLY NO DWG FILE

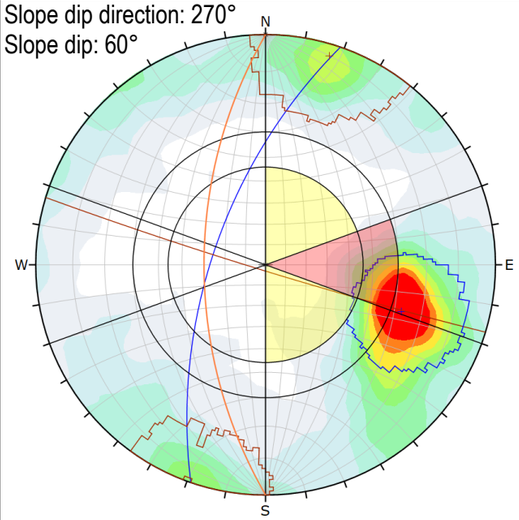
Rev.

BLUEBEAM

DO NOT SCALE

IF IN DOUBT ASK.

Slope dip direction: 270°
Slope dip: 60°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

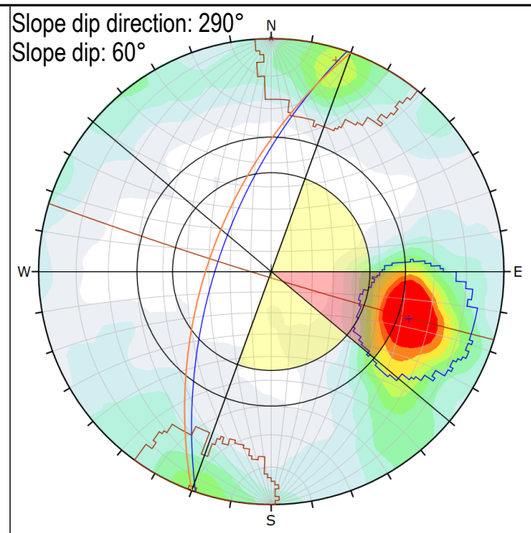
Kinematic Analysis	Direct Toppling
Slope Dip	60
Slope Dip Direction	270
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	0	328860	0.00%
Base Plane (All)	417	3235	12.89%
Base Plane (Set 1: Set 1)	168	812	20.69%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 290°
Slope dip: 60°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

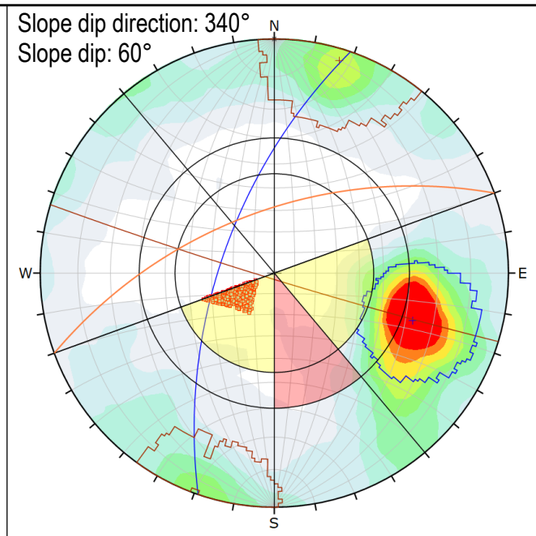
Kinematic Analysis	Direct Toppling
Slope Dip	60
Slope Dip Direction	290
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	0	328860	0.00%
Base Plane (All)	511	3235	15.80%
Base Plane (Set 1: Set 1)	269	812	33.13%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 340°
Slope dip: 60°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

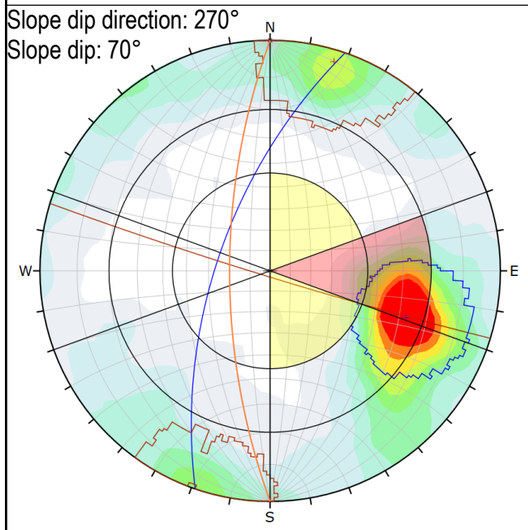
Kinematic Analysis	Direct Toppling
Slope Dip	60
Slope Dip Direction	340
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	23172	328860	7.05%
Base Plane (All)	310	3235	9.58%
Base Plane (Set 1: Set 1)	6	812	0.74%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 270°
Slope dip: 70°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

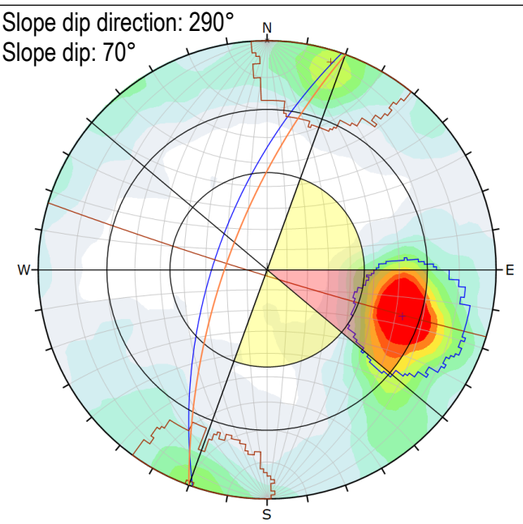
Kinematic Analysis	Direct Toppling
Slope Dip	70
Slope Dip Direction	270
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	0	328860	0.00%
Base Plane (All)	652	3235	20.15%
Base Plane (Set 1: Set 1)	354	812	43.60%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 290°
Slope dip: 70°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

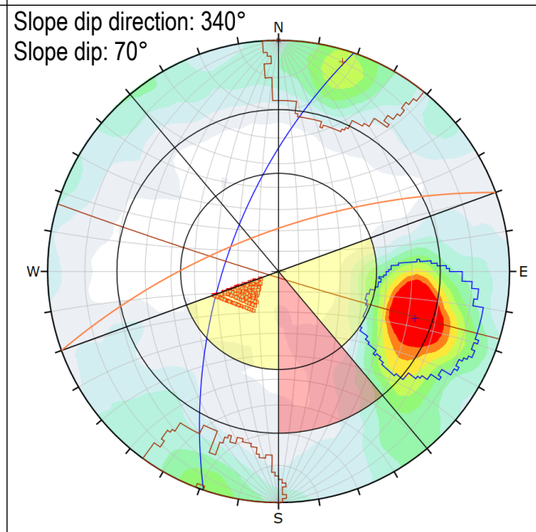
Kinematic Analysis	Direct Toppling
Slope Dip	70
Slope Dip Direction	290
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	0	328860	0.00%
Base Plane (All)	819	3235	25.32%
Base Plane (Set 1: Set 1)	577	812	71.06%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 340°
Slope dip: 70°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

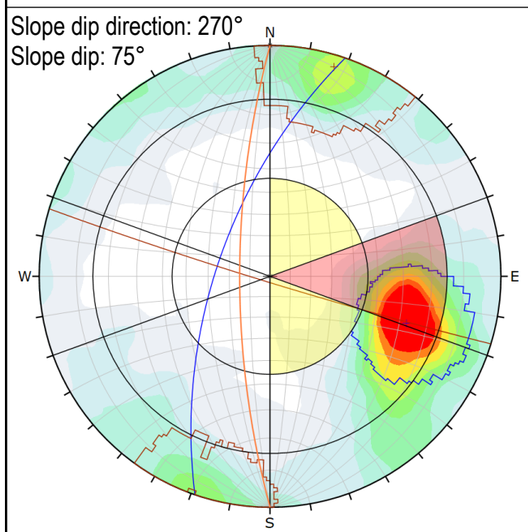
Kinematic Analysis	Direct Toppling
Slope Dip	70
Slope Dip Direction	340
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	23172	328860	7.05%
Base Plane (All)	365	3235	11.28%
Base Plane (Set 1: Set 1)	6	812	0.74%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 270°
Slope dip: 75°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

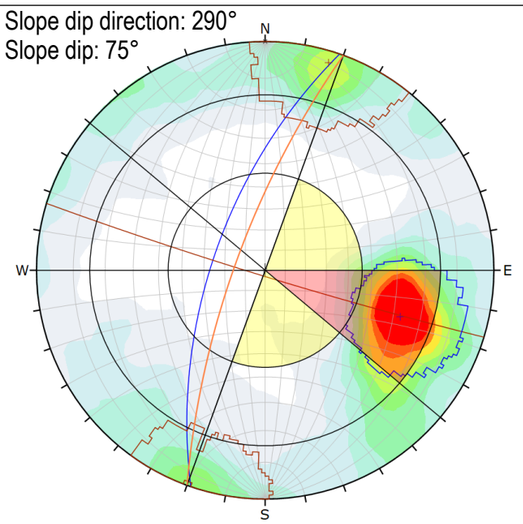
Kinematic Analysis	Direct Toppling
Slope Dip	75
Slope Dip Direction	270
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	0	328860	0.00%
Base Plane (All)	711	3235	21.98%
Base Plane (Set 1: Set 1)	402	812	49.51%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 290°
Slope dip: 75°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

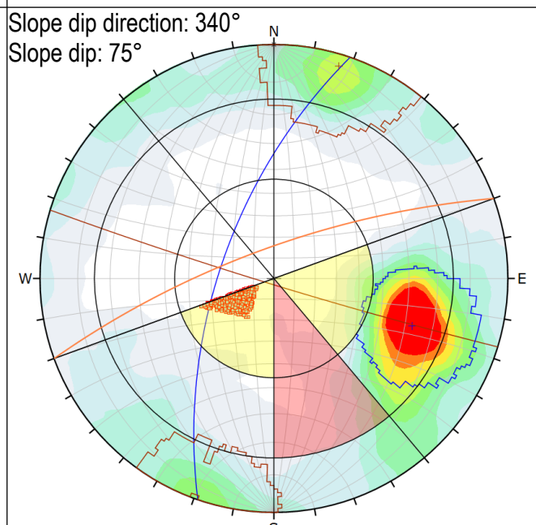
Kinematic Analysis	Direct Toppling
Slope Dip	75
Slope Dip Direction	290
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	0	328860	0.00%
Base Plane (All)	934	3235	28.87%
Base Plane (Set 1: Set 1)	684	812	84.24%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

Slope dip direction: 340°
Slope dip: 75°



Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Direct Toppling
Slope Dip	75
Slope Dip Direction	340
Friction Angle	46°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	328860	0.00%
Oblique Toppling (Intersection)	23172	328860	7.05%
Base Plane (All)	403	3235	12.46%
Base Plane (Set 1: Set 1)	6	812	0.74%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		64	289	Set 1
2m		87	197	Set 2

Plot Mode	Pole Vectors
Vector Count	3235 (3235 Entries)
Intersection Mode	All Set Planes
Intersections Count	328860
Hemisphere	Lower
Projection	Equal Angle

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No.	Revision	By	Chk	Appd	Date

Drawing Originator: CONNECT WATER

Original Scale (A1)	Design	
	Drawn	
Reduced Scale (A3)	Dsg Verifier	
	Dwg Check	

* Refer to Revision 1 for Original Signature

Client: WELLINGTON WATER

Project: WELLINGTON SLUDGE MINIMISATION FACILITY (SMF)

Title: SECTOR 2: EASTERN AND SOUTHEASTERN SLOPES. KINEMATIC ANALYSES FOR DIRECT TOPPLING

Discipline: GEOTECHNICAL

Drawing No.: PDF ONLY NO DWG FILE

Rev.

BLUEBEAM

DO NOT SCALE

IF IN DOUBT ASK.

CONNECT WATER

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